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U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE

ATTORNEY'S DOCKET NUMBER

TRANSMITTAL LETTER TO THE UNITED STATES
DESIGNATED/ELECTED OFFICE (DO/EO/US)
CONCERNING A FILING UNDER 35 U.S.C. 371

Hessler 1-1-1-3

U.S. APPLICATION NO. (If known, see 37 CFR 1.5)

09/937367

INTERNATIONAL APPLICATION NO.

PCT/1B00/00419

INTERNATIONAL FILING DATE

March 28, 2000

PRIORITY DATE CLAIMED

March 29, 1999

TITLE OF INVENTION Detection and Compensation of Ingressing Frame Offset
Discontinuities for Tandem Connection TrailsAPPLICANT(S) FOR DO/EO/US Peter Hessler; Manfred Alois Loeffler; Jurgen Milisterfer;
Maarten Petrus Viissers

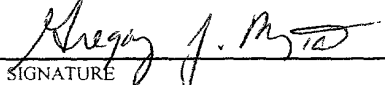
Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. ☒ This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. ☐ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. ☒ This is an express request to begin national examination procedures (35 U.S.C. 371(f)). The submission must include items (5), (6), (9) and (21) indicated below.
4. ☒ The US has been elected by the expiration of 19 months from the priority date (Article 31).
5. ☒ A copy of the International Application as filed (35 U.S.C. 371(c)(2))
 - a. ☐ is attached hereto (required only if not communicated by the International Bureau).
 - b. ☒ has been communicated by the International Bureau.
 - c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US).
6. ☒ An English language translation of the International Application as filed (35 U.S.C. 371(c)(2)).
 - a. ☐ is attached hereto.
 - b. ☒ has been previously submitted under 35 U.S.C. 154(d)(4).
7. ☒ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371(c)(3))
 - a. ☒ are attached hereto (required only if not communicated by the International Bureau).
 - b. ☐ have been communicated by the International Bureau.
 - c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.
 - d. ☐ have not been made and will not be made.
8. ☐ An English language translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371 (c)(3)).
9. ☒ An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)).
10. ☐ An English language translation of the annexes of the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)).

Items 11 to 20 below concern document(s) or information included:

11. ☒ An Information Disclosure Statement under 37 CFR 1.97 and 1.98.
12. ☒ An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
13. ☒ A FIRST preliminary amendment.
14. ☐ A SECOND or SUBSEQUENT preliminary amendment.
15. ☒ A substitute specification.
16. ☐ A change of power of attorney and/or address letter.
17. ☐ A computer-readable form of the sequence listing in accordance with PCT Rule 13ter.2 and 35 U.S.C. 1.821 - 1.825.
18. ☐ A second copy of the published international application under 35 U.S.C. 154(d)(4).
19. ☐ A second copy of the English language translation of the international application under 35 U.S.C. 154(d)(4).
20. ☐ Other items or information:

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| U.S. APPLICATION NO. (if any) 09/937367 | | INTERNATIONAL APPLICATION NO. | | ATTORNEY'S DOCKET NUMBER | |
| 21. <input checked="" type="checkbox"/> The following fees are submitted: BASIC NATIONAL FEE (37 CFR 1.492 (a) (1) - (5)): Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO and International Search Report not prepared by the EPO or JPO. \$1000.00 International preliminary examination fee (37 CFR 1.482) not paid to USPTO but International Search Report prepared by the EPO or JPO \$860.00 International preliminary examination fee (37 CFR 1.482) not paid to USPTO but international search fee (37 CFR 1.445(a)(2)) paid to USPTO \$710.00 International preliminary examination fee (37 CFR 1.482) paid to USPTO but all claims did not satisfy provisions of PCT Article 33(1)-(4) \$690.00 International preliminary examination fee (37 CFR 1.482) paid to USPTO and all claims satisfied provisions of PCT Article 33(1)-(4) \$100.00 ENTER APPROPRIATE BASIC FEE AMOUNT = | | | | CALCULATIONS PTO USE ONLY | |
| | | | | | |
| Surcharge of \$130.00 for furnishing the oath or declaration later than <input type="checkbox"/> 20 <input type="checkbox"/> 30 months from the earliest claimed priority date (37 CFR 1.492(e)). | | | | \$ - | |
| CLAIMS | NUMBER FILED | NUMBER EXTRA | RATE | \$ | |
| Total claims | 20 - 20 = | 0 | x \$18.00 | \$ - | |
| Independent claims | 2 - 3 = | 0 | x \$80.00 | \$ - | |
| MULTIPLE DEPENDENT CLAIM(S) (if applicable) | | | + \$270.00 | \$ - | |
| TOTAL OF ABOVE CALCULATIONS = | | | | \$ 860.00 | |
| <input type="checkbox"/> Applicant claims small entity status. See 37 CFR 1.27. The fees indicated above are reduced by 1/2. | | | | \$ - | |
| SUBTOTAL = | | | | \$ 860.00 | |
| Processing fee of \$130.00 for furnishing the English translation later than <input type="checkbox"/> 20 <input type="checkbox"/> 30 months from the earliest claimed priority date (37 CFR 1.492(f)). | | | | \$ - | |
| TOTAL NATIONAL FEE = | | | | \$ 860.00 | |
| Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31). \$40.00 per property + | | | | \$ 40.00 | |
| TOTAL FEES ENCLOSED = | | | | \$ 900.00 | |
| | | | | Amount to be refunded: | \$ |
| | | | | charged: | \$ |
| a. <input type="checkbox"/> A check in the amount of \$ _____ to cover the above fees is enclosed. b. <input checked="" type="checkbox"/> Please charge my Deposit Account No. <u>12-2325</u> in the amount of \$ <u>900.00</u> to cover the above fees. A duplicate copy of this sheet is enclosed. c. <input checked="" type="checkbox"/> The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. <u>12-2325</u> . A duplicate copy of this sheet is enclosed. d. <input type="checkbox"/> Fees are to be charged to a credit card. WARNING: Information on this form may become public. Credit card information should not be included on this form. Provide credit card information and authorization on PTO-2038. | | | | | |
| NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137 (a) or (b)) must be filed and granted to restore the application to pending status. | | | | | |
| SEND ALL CORRESPONDENCE TO Docket Administrator Lucent Technologies Inc. Room 3J-219 101 Crawfords Corner Road Holmdel, NJ 07733-3030 | | |  SIGNATURE Gregory J. Murgia NAME 41,209 REGISTRATION NUMBER | | |

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IN THE UNITED STATES
PATENT AND TRADEMARK OFFICE

Patent Application

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Case Hessler 1-1-1-3

Serial No.

Filing Date

Examiner

Group Art Unit

Title DETECTION AND COMPENSATION OF INGRESSING FRAME OFFSET
DISCONTINUITIES FOR TANDEM CONNECTION TRAILS

ASSISTANT COMMISSIONER FOR PATENTS
WASHINGTON, D.C. 20231

PRELIMINARY AMENDMENT

Sir:

Prior to examination of the above-identified application, please enter the following amendments and remarks.

In the Specification

Substitute the attached specification (Attachment 1) in its entirety for the one currently pending.

In the Claims

Cancel claims 1-21.

Add new claims 22-41 as follows:

1 - - **22.** A method of transmitting data in a synchronous hierarchic network system
2 comprising at least a path segment between a first network element and at least a second
3 network element on which tandem connection monitoring method is established for monitoring
4 transmission of information over the path segment, the method comprising:
5 detecting frame offset discontinuities at the first network element on the basis of
6 detection of an alteration of a pointer value.

1 **23.** The method according to claim **22**, wherein a discontinuity condition is signalled
2 to an equipment management system.

1 **24.** The method according to claim **23**, wherein signalled discontinuity condition
2 information is stored in a transmission quality report.

1 **25.** The method according to claim **22**, wherein a discontinuity condition detected at
2 the first network element is transmitted to the second network element.

1 **26.** The method according to claim **25**, wherein the discontinuity condition detected
2 at the first network element is transmitted within a defined data element of a virtual container
3 transmitted to the second network element.

1 **27.** The method according to claim **26** wherein, after detection and signalling of the
2 discontinuity condition, the second network element suspends counting and evaluation of
3 certain tandem connection errors and defect information for a predefined interval of time.

1 **28.** The method according to claim **25**, wherein the discontinuity condition is
2 signalled from the second network element to an equipment management system.

1 **29.** The method according to claim **28**, wherein signalled discontinuity condition
2 information is stored in a transmission quality report.

1 **30.** The method according to claim **22** wherein, after detection of a discontinuity
2 condition, transmitted pointer values are altered stepwise at the first network element.

1 **31.** The method according to claim **30**, wherein stepwise alteration comprises:
2 a pointer value adjustment towards a new valid pointer value; and
3 at each step, introduction of a pointer value difference which is within a standardized
4 range of pointer increment or decrement operations.

1 **32.** The method according to claim **31**, wherein the distance between a last valid
2 pointer value before and the new valid pointer value after the detected discontinuity condition is
3 used to evaluate and select a shortest difference for a stepwise adaptation of the pointer values.

1 **33.** The method according to claim **32** wherein, in case of similar differences for
2 increasing or decreasing of the pointer value, the direction of pointer drift before the
3 discontinuity condition occurred is used to determine a direction for the stepwise adaptation of
4 the pointer values.

1 **34.** The method according to claim **30** wherein, during a time interval necessary for
2 detection and transmission of a frame offset discontinuity, a last valid pointer value received in
3 advance of the discontinuity condition is transmitted.

1 **35.** The method according to claim **22**, wherein the first network element operates as
2 a source network element and the second network element operates as a sink network element.

1 **36.** A synchronous hierarchic network system adapted for data transmission
2 involving at least a path segment between a first network element and at least a second network
3 element on which a tandem connection monitoring method is established for monitoring
4 information over the path segment, the system comprising:

5 a detector for detecting frame offset discontinuities on the basis of the detection of an
6 alteration of a pointer value.

1 **37.** The system according to claim **36**, further comprising means for signalling a
2 frame offset discontinuity condition to an equipment management system.

1 **38.** The system according to claim **37**, further comprising means for receiving and
2 storing discontinuity condition information received from the detector.

1 **39.** The system according to claim **36**, further comprising means for evaluating and
2 altering pointer values.

1 **40.** The system according to claim **36**, further comprising means for transmitting a
2 discontinuity condition detected at the first network element to the second network element.

1 **41.** The system according to claim **36**, further comprising means for suspending
2 counting and evaluation of certain tandem connection errors and defect information for a
3 predefined interval of time. - -

REMARKS

Status of the Case

By this preliminary amendment, originally filed claims 1-21 have been canceled and new claims 22-41 have been added. As such, claims 22-41 are now pending in the application.

In the Claims

Applicants submit that the addition of new claims 22-41 is fully supported by the disclosure in the original claims as well as in the specification and therefore no new matter has been introduced. In particular, new claims 22-41 are essentially equivalent to originally-filed claims 1-21, except that changes have been made to address matters of form resulting from the differences between European and U.S. claim formats and techniques.

In the Specification

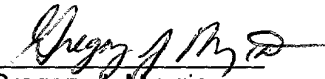
The substitute specification (Attachment 1) is being provided to correct various matters of form in the international PCT application. For example, Applicants have added various subtitles to more clearly define the various parts of the specification in accordance with standard U.S. convention. Applicants have also corrected several grammatical and typographical errors and omissions and have removed paragraph numbering used in the international PCT application. Finally, Applicants have amended the "Abstract of the Disclosure" to conform to standard U.S. convention. Applicants submit that the substitute specification does not introduce new matter in that the changes find support in the originally-filed international PCT application.

The marked-up version of the specification as filed in the international PCT application is provided at Attachment 2 ("VERSION WITH MARKINGS TO SHOW CHANGES MADE"). Changes are annotated by underlining for added material and bracketing for deleted material.

Conclusion

In view of the foregoing, consideration of this application is respectfully requested. Any questions can be directed to the Applicants' attorney at the number below.

Respectfully submitted,

By: 
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Reg. No. 41,209
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Lucent Technologies Inc.
Date: 9/21/01

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Detection and Compensation of Ingressing Frame Offset Discontinuities for Tandem Connection Trails

Technical Field

5 The invention relates to the detection and compensation of frame offset discontinuities for tandem connection trails in general and especially to frame offset discontinuities occurring at the entrance of a network element in a Synchronous Digital Hierarchy (SDH) and Synchronous Optical Network (SONET) system.

Background of the Invention

10 The problem addressed with this invention typically arises in Synchronous Digital Hierarchy (SDH) and Synchronous Optical Network (SONET) systems in the case of switching of parts of a network path due to a failure condition or in case of a faulty or defect part of the network path. For a deeper understanding of SDH and SONET systems, reference is made to "Understanding of SONET/SDH", ISBN 0-9650448-2-3,
 15 Andan Publisher, New Jersey. In the before-mentioned network systems a tandem connection is intended to provide an administrative monitoring domain which is operating independent of the end to end path. Errors and faults outside the tandem connection should not be noticed in the tandem connection performance monitoring and fault management itself. However, the existing tandem connection equipment specifications
 20 in ETSI EN300 417-4-1 and ITU-T G.783 do not support this independence under all conditions especially if frame offset discontinuities occur. A frame offset discontinuity is a change of the pointer's value which defines the flexible start position of the Virtual Container within the SDH frame or an overflow or underflow of the elastic store used to adapt the ingressing data stream to the system frequency. Pointer justifications (i.e.
 25 increment and decrement operations) also change the value of the pointer but they are not frame offset discontinuities in the sense of or according to the definition as used in connection with this invention.

 On every incoming frame offset discontinuity of the Virtual Container (VC) within the SDH frame, the tandem connection performance monitoring system will detect
 30 errored blocks and therefore declare one or two errored seconds (during which data are declared to be faulty or errored). Also Tandem Connection (TC) alarms may be raised.

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These undesirable effects are caused by the fact that Pointer Processors (PP) are used in the network elements for the adaptation of the frequency of the incoming signal to the internal frequency of the network element and for accessing the virtual containers.

5 The transport of frame offset discontinuities through the network (series of pointer processors) will be fast (few bytes delay per Pointer Processor) in the virtual container signal, and much slower in the Administrative Unit (AU) or Tributary Unit (TU) (0 to 1 frame delay per pointer processor). For a certain amount of time the frame start indication, i.e. the pointer at the tandem connection sink node is not aligned with the
10 actual phase of the virtual container. Information will be read from the wrong byte positions during this period of misalignment. This effect increases with the number of pointer processors in the chain.

 The problem for tandem connection trails is introduced by the fact that there is no separate layer to transport the tandem connection information and that the path
15 (virtual container) layer is used instead. Therefore interruptions on the path (virtual container) layer also influence the tandem connection layer.

Summary of the Invention

 According to the principles of the invention, the influence of frame offset discontinuities occurring at the beginning of a Tandem Connection Trail in a
20 Synchronous Digital Hierarchy (SDH) or in a Synchronous Optical Network (SONET) System is reduced.

 More specifically, frame offset discontinuities are detected and relayed to a network management system where this information is further utilized to initiate predefined process steps.

25 In one illustrative embodiment of the invention, the signalled information is processed and stored as a kind of transmission quality protocol for a segment of the respective network path provided to a customer. As a consequence thereof, a network provider is enabled to show that the distortion or the fault condition was not caused within the providers network path segment but was received at the entrance or input of
30 the path segment.

 If the discontinuity condition detected at network element A is transmitted to network element B, which process also is termed throughout the description of the

invention as "frame offset discontinuity inband signalling", then a provider may collect this information for establishing a transmission quality report and filter out faulty or distorted periods of transmission. In addition, storing of the quality data will reveal at any later point of time that, even if certain incoming data were faulty, these data were
5 transmitted essentially without additional distortions along the providers network path segment.

In another illustrative embodiment, after detection of a discontinuity condition, transmitted pointer values are altered stepwise towards a new valid pointer value (i.e. a valid value after occurrence of the offset discontinuity). Due to the stepwise alteration an
10 uninterrupted or contiguous adaptation from an early undistorted transmission condition to a new undisturbed transmission condition for the TC-relevant data is obtained for the downstream network elements. This adaptation is also named a "smooth" pointer adaptation in the course of the further detailed description.

Advantageously, faster smooth adaptation can be obtained if the distance
15 between the last valid pointer value before and the new valid pointer value after the detected discontinuity condition is used to evaluate and select the shortest difference for the stepwise adaptation of the pointer values.

In another illustrative embodiment of the invention, the pointer values of a pointer, as received in advance of the discontinuity condition, are transmitted during the
20 time interval used to evaluate the necessary pointer actions (in case of smooth pointer adaptation) or to signal the discontinuity (in case of inband signalling) to avoid transmitting of faulty TC-relevant data during this time interval.

If, after detection and signalling of the discontinuity condition, the tandem connection monitoring (TC) system suspends counting and evaluating of errors and
25 failures for a predefined interval of time and this interval of time is chosen to be sufficient for covering the period of time necessary for compensating the discontinuity condition, suspending is of no negative influence but beneficial as it is not desired to report any TC failures and errors caused by the ingressing discontinuity.

Moreover, in case that after detection of the discontinuity condition, collection or
30 reporting of errors and failures is interrupted for a predefined interval of time and this interval of time is chosen to be long enough for covering the period of time necessary for compensating the discontinuity condition, it is ascertained that a provider receives only

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undistorted TC-relevant data. It is assumed that the necessary interval of time during which the data transmission fails is within the allowed range for the relevant network applications.

Brief Description of the Drawings

5 The invention is described in more detail in connection with the appended drawings in which:

 Fig. 1 shows the functional model for a VC-4 path from Network Domain I via Network Domain II to Network Domain III with an embedded VC-4 tandem connection trail in Network Domain II between Network Elements (NE) A and B;

10 Fig. 2 details a High-Level View of an exemplary SDH System Architecture;

 Fig. 3 shows a block overview of a smooth pointer adaptation at the TCM Source Function Block;

 Fig. 4 explains different cases for a pointer distance calculation for the smooth pointer adaptation mode;

15 Fig. 5 shows a block overview of frame offset discontinuity inband signalling at the TCM Source Function Block;

 Fig. 6 shows a block overview of frame offset discontinuity signalling at the TCM Sink and TCM NIM function block; and

 Fig. 7 shows a freeze process for TCM Sink and TCM NIM Defect Evaluation.

20 **Detailed Description**

 Language, terminology and definitions are used throughout the description and in the claims in accordance to the respective international and national standard notation, i.e. unless other definitions were made in view of specific terms.

Definitions and Glossary

25 In addition to definitions given in the introductory portion of the description, a synchronous hierarchic system according to the invention is an SDH or SONET system or a system including path sections between network elements NE including the essential features of SDH or SONET systems.

 The term "frame offset discontinuity" in connection with the invention is intended
30 to cover an alteration of the pointer value other than an increment or decrement operation that is introduced by the network system and an ingressing discontinuity is

meant to cover a discontinuity received by or entering a network element NE.

Even if in the following description of the most preferred embodiments only an SDH application is described, the essential principle is also applicable to SONET systems.

5 Figure 1 shows the functional model for a VC-4 path from Network Domain I via Network Domain II to Network Domain III with an embedded VC-4 tandem connection trail in Network Domain II between Network Elements (NE) A and B. The network elements (NEs) A and B are connected via an optical STM-1 link and both NEs are connected to Network Domain I and III via an optical STM-4 link.

10 The standards define that in NE A a pointer interpreter is in the adaptation sink function MS4/S4 and a pointer generator in the adaptation source function MS1/S4 with the Tandem Connection Adaptation Source S4D/S4 function and the TC TT Source S4D function between. For the reverse direction there is a pointer interpreter in the adaptation sink function MS1/S4 and a pointer generator in the adaptation source function MS4/S4
15 with the TC Adaptation Sink function S4D/S4 and the TC TT Sink function S4D between. In principle the same applies for NE B. The following mechanism is used at the TC Adaptation Source function on the transition into an SSF condition (holdover mode): The adaptation sink function MS4/S4 receives a signal with incorrect pointer values. It will count the number for some frames (3 if AIS in pointer, 8 if invalid pointer). During this
20 period the frame start signal CI FS is maintained and the SSF indication signal CI SSF is inactive (=FALSE). On detection of a defect (dAIS or dLOP), CI_FS becomes invalid and CI_SSF becomes active (=TRUE). Furthermore, all-1's is inserted into the VC-4 signal. The TC Adaptation Source function S4D/S4 detecting the change in CI FS and CI SSF,
25 enters "holdover" state in its Frame Start circuit, and continues to generate the frame start signal AI FS at the same position as before. It will also activate the signal fail indication signal AI SF.

30 The TC Trail Termination Source function S4D will continue to receive a valid AI FS signal at the same position as before. It will also receive an active AI SF signal and will insert the IncAIS Code (N1[1-4]=1110) into the signal. Signalling of IncAIS must not start before the mismatch between B3 and the BIP-8 calculated over the previous frame (caused by the start of the all-ones-insertion) is cleared, i.e. not before a complete frame has been overwritten with all-ones. This is not explicitly described in the standards, but is

essential to prevent the detection of TC bit errors at the far end. Therefore this procedure is considered as state of the art and is not further mentioned in the following text. The IncAIS code point in the IEC (=Incoming Error Code) field is interpreted as zero errors at the far end, which is correct for the transmission of VC-AIS. During the defect

5 detection time in the adaptation sink function MS4/S4, mismatches between calculated BIP-8 and B3 will be detected as there is an access to a random B3 byte position. They are correctly encoded into the IEC field. As such, the transition will not result in the detection of any errors in the TC. The adaptation source function MS1/S4 receives a continuous CI FS and will not change its pointer value.

10 In principle an arbitrary frame start discontinuity can also be detected as a change of the frame start signal CI FS entering the TC Adaptation Source function S4D/S4.

However many implementations do not follow the standards with respect to the locations of the pointer interpreter and the pointer generator, but have a combined

15 pointer interpreter/generator in the adaptation sink function MSx/ S4 and no further pointer handling in the adaptation source function MSx/S4. Therefore a frame offset discontinuity entering the network element with the TC Adaptation Source function is not always accompanied by a new data flag (NDF) in the pointer. Following this kind of implementation also means that the TC Adaptation Source function S4D/S4 must have

20 the functionality of pointer generation in case of SSF (holdover mode).

Scenarios which cause frame offset discontinuities in the network in front of the TC Adaptation Source are listed below. It is also shown which resulting pointer transitions are input to the NE with the TC Adaptation Source function:

- 25 • Recovery from Server Signal Fail (SSF) condition (Loss of Pointer (LOP)/AU/TU-AIS) as a result of the repair of a fault or of a protection switch (initiated by a SSF condition)

In this case, the pointer transitions are:

- SSF -> New Data Flag (NDF) -> Norm
- SSF -> Norm

- 30 • Establishment of a different path as a result of a crossconnect change in front of the tandem connection trail. In this case, the pointer transitions are (this also includes signal changes where typically an Unequipped Signal is used):

— Norm1 -> NDF -> Norm2

— Norm1 -> Norm2

- Change of phase alignment of byte-synchronously mapped plesiochronous signals. (An example is described in EN 300 417-4-1, Annex C.). In this case, the pointer transitions are:

— Norm1 -> NDF -> Norm2

- Protection switches caused by external commands (manual or forced switch), by revertive operation mode or by condition changes which do not affect the pointer (e.g. Signal Degrade). In this case, the pointer transitions are:

— Norm1 -> NDF -> Norm2

— Norm1 -> Norm2

The transition from a valid signal into SSF is also a frame offset discontinuity. As this case is considered already in the standards ("Holdover mode for the TC Adaptation Source function") it is not an issue of the further discussion.

To solve the problem, frame offset discontinuities need to be detected at the TC Adaptation Source function. After detection, either an error free tandem connection signal can be inserted at the TC Trail Termination Source function or the frame offset discontinuity can be communicated to the TC Trail Termination Sink function and TC Non-intrusive Trail Termination Sink function to suspend the performance monitoring and the evaluation of the tandem connection defects there for an appropriate period of time.

Frame Offset Discontinuity Detection

An incoming frame offset discontinuity occurs if a pointer value is received different from the previous one with NDF set or if three consecutive new, valid and identical pointer values are received without NDF set. Normal stuffing actions are not frame offset discontinuities.

Therefore the detection of the frame offset discontinuity can be achieved by searching for both:

- the New Data Flag enabled in the incoming pointer; and
- three times detection of a new pointer value without NDF (New Pointer Value

(NPV)).

The pointer transitions that need to be detected are shown in EN 300 417-1-1, Annex B. Figure B1 in this annex shows the pointer interpretation states. All states marked with "NDF_enable" or "3*new_point" are frame offset discontinuities as described above.

Procedures to Compensate the Effects of Ingressing Frame Offset Discontinuities

To improve the behaviour of tandem connection trails with respect to ingressing frame offset discontinuities it is intended according to the invention to:

- suppress the propagation of frame offset discontinuities into the tandem connection trail by converting the frame offset discontinuities to series of pointer justifications;
- signal the incoming frame offset discontinuity to the TC Trail Termination (TC TT) Sink function and TC Non-intrusive Trail Termination (TC NIM TT) Sink functions and suspend counting and reporting of errors and defects there for a certain period of time; and
- signal the detected frame offset discontinuity to the network element management and network management system for further processing. (The reporting is done towards the Equipment Management Function (EMF) and then e.g. via the Q-interface to the network element management system.)

Smooth Pointer Adaptation

The frame offset discontinuity within the tandem connection trail can be completely suppressed by changing the pointer generation in the Network Element containing the TC Adaptation Source. The idea is to "smooth" the frame offset discontinuity by converting it to a series of consequent pointer actions (increment or decrement) instead of following the jump immediately.

In a first option the distance of the old and new pointer is not taken into account to choose the shortest way of adaptation, but either a sequence of positive or negative justifications is used to go from the last valid pointer value to the new pointer value.

In a second option in order to keep the recovery time for this method as short as possible, the distance between the last valid pointer value and the new valid value after

As a further enhancement (third option) the drift direction of the incoming pointer may be evaluated and used for the decision which stuffing direction should be used. This enhancement can be used if the distance for positive and negative justifications is nearly equal.

As soon as the pointer insertion reaches the same pointer value as the incoming signal, a check of the inserted pointer versus the incoming pointer sequence is necessary. If the inserted pointer value is at least three times identical to the incoming pointer, the insertion can be switched off. This check is necessary to prevent the creation of invalid pointer sequences (only every four frames pointer justifications are allowed).

According to this method, the frame offset discontinuity must not be propagated into the tandem connection trail during the detection period of the frame offset discontinuity (i.e. until the smooth pointer adaptation starts).

Frame Offset Discontinuity Inband Signalling

The idea of the method of frame offset discontinuity (FOD) inband signalling is to delay the incoming frame offset discontinuity by introducing a holdover mode by a few

virtual container frames so that the appearance of a frame offset discontinuity can be communicated within the tandem connection trail from the TC Adaptation Source function to the TC TT Sink function and intermediate TC NIM TT Sink functions.

After detection of the frame offset discontinuity, the pointer generation of the
5 Network Element containing the tandem connection source function shall continue to transmit the pointer value used before the frame offset discontinuity (holdover mode). This is similar to the method used for the transition into SSF.

During the holdover time, a signalling code is inserted in the Tandem Connection Path Overhead (i.e. N1 for VC-4/3 and contiguous concatenated VC-4-Xc TC, N2 for
10 VC-2/12/11 TC). This code must be selected such that it is not used during normal tandem connection operation and it should be selected such that the operation of Performance Monitoring and Fault Management is not disturbed. For VC-4/3 and VC-4-Xc TC, a correction of the B3 byte may be necessary, depending on the inserted signalling code.

15 To keep the holdover phase as short as possible it is recommended to use N1/N2 bits repeated every VC-frame (i.e. bits within the 76 frames tandem connection multiframe should not be used).

The signalling sequence shall be such that a safe transmission even with up to one bit error in the sequence is possible. After the frame offset discontinuity is signalled,
20 the frame offset discontinuity can be propagated into the tandem connection trail.

An alternative option when doing this is not to immediately switch over to the new pointer value after the end of the signalling sequence, but instead to take care that a correct sequence of pointer values is maintained.

At the TC TT Sink function, the frame offset discontinuity code shall be detected
25 out of the N1/N2 bytes. The detection shall tolerate at least one bit error in the signalling code.

After reception of the frame offset discontinuity code, the signal can be assumed as defective for a fixed period of time. During this period, the TC TT Sink function and TC NIM TT Sink function shall stop the accumulation of errors and suspend the usage of
30 tandem connection defects for fault processing and defect second detection. Furthermore, the TC NIM TT Sink function shall suspend the usage of tandem connection defects for sub network connection protection (SNCP) switching.

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For this method, the frame offset discontinuity must not be propagated into the TC trail until it is completely signalled.

Frame Offset Discontinuity Reporting

The reporting of frame offset discontinuities can be done directly at the TC
5 Adaptation Source function or (with FOD inband signalling as described above) at the TC TT Sink function or TC NIM TT Sink function.

The reported frame offset discontinuities can be used for event logging or performance monitoring.

Application Example

10 In the TCM application, the described compensation modes can be activated and used separately per tandem connection trail. So by means of the network element or network management system each tandem connection trail can be adapted to the needs of the planned network application. If the compensation modes are disabled, the TCM function behaves as required by the current standards. The third mechanism, to report
15 the detected incoming frame offset discontinuities, is implemented in parallel.

In the application example the functionality of the TC Adaptation Source function and of the TC TT Source function is implemented by the TCM Source function block, that of the TC Adaptation Sink function and of the TC TT Sink function by the TCM Sink function block and that of the TC NIM TT Sink function by that of the TC NIM function
20 block.

Frame Offset Discontinuity Detection

This part is common for all proposed mechanisms. The goal of the frame offset discontinuity detection is to detect all incoming frame offset discontinuities. As stated above, the pointer transitions that need to be detected are shown in EN 300 417-1-1,
25 Annex B. Figure B1 in this annex shows the pointer interpretation states. All states marked with "NDF_enable" or "3*new_point" are frame offset discontinuities.

In one exemplary SDH system manufactured by Lucent Technologies, a pointer processing unit is located in front of the TCM Source function block. The described application relies on the fact that the frame offset discontinuities are detected in the
30 pointer processor unit so that only valid pointers or AU/TU-AIS conditions arrive at the

TCM Source function block. The high level view of this exemplary system architecture is given by Figure 2 .

The table below shows how incoming frame offset discontinuities are converted by the pointer processor unit in front of the TCM Source function block.

5

| Input to PP Unit: Transition | Input to PP Unit: Condition | Input to TCM Source function block: Pointer sequence generated at PP Unit |
|---------------------------------|--------------------------------|--|
| INC -> NDF | NDF_enable set | Norm -> NDF_enable -> Norm |
| DEC -> NDF | NDF_enable set | Norm -> NDF_enable -> Norm |
| NDF -> NDF | NDF_enable set | Norm -> NDF_enable -> Norm |
| Norm -> NDF | NDF_enable set | Norm -> NDF_enable -> Norm |
| AIS -> NDF | NDF_enable set | AU/TU-AIS -> NDF_enable -> Norm |
| Norm -> Norm | 3*new_point | Norm -> NDF_enable -> Norm |
| INC -> Norm | 3*new_point | Norm -> NDF_enable -> Norm |
| DEC -> Norm | 3*new_point | Norm -> NDF_enable -> Norm |
| NDF -> Norm | 3*new_point | Norm -> NDF_enable -> Norm |
| LOP -> Norm | 3*new_point | AU/TU-AIS -> NDF_enable -> Norm |
| AIS -> Norm | 3*new_point | AU/TU-AIS -> NDF_enable -> Norm |

Looking at the generated pointer sequences in the table above it can be seen that all incoming frame offset discontinuities arrive at the TCM Source function block as a pointer with the NDF_enable set. However, there may be some older equipment which doesn't generate NDF while going from AU/TU-AIS to Norm.

10

Therefore the conditions that need to be detected at the TCM Source function block are:

- NDF_enable
- Transition AIS -> Non-AIS

15

For this detection, it is sufficient to check the H1/V1 byte for the following conditions:

- NDF_enable, i.e. NDF-bits in H1/V1 set to "1001". It is not necessary to check for the other valid NDF_enable values, the ss-bit match and the pointer offset value because the transmission from pointer processor unit to TCM source function is system-internal and can be assumed as error-free; and

20

- Transition from an "all-ones" in H1/V1 to any other value to detect the AU/TU-AIS to Non-AIS transition in case of missing NDF (interworking with old pointer processor units which might not generate an NDF).

The two conditions above are detected by a simple one-time pattern match check of the incoming H1/V1 byte per virtual container at the TCM Source function block. The detected frame offset discontinuities are made available for reporting towards the network element management.

Smooth Pointer Adaptation

For the smooth pointer adaptation a pointer interpreter and pointer generator with only limited functionality (regarded to what's required in the standards) is implemented. Figure 3 shows a block diagram of the smooth pointer adaptation mechanism at the TCM Source function block.

The pointer interpreter at the TC Adaptation Source function always stores the last valid pointer value. This can be either the last pointer value before entering SSF (if the TC Trail Adaptation Source goes in holdover mode) or the pointer value contained in the AU/TU frame before the frame offset discontinuity. During the smooth pointer adaptation phase, the stored received pointer value is replaced by the last inserted pointer value. At the occurrence of a frame offset discontinuity, this pointer value is communicated to the TC Adaptation part of TCM Source function block where it is inserted into the outgoing pointer.

As soon as a new valid pointer is available (i.e. directly after the frame offset discontinuity), the pointer distance between the new valid pointer and the stored pointer value is measured to decide the stuffing direction for the inserted pointer.

Figure 4 shows how the pointer distance is calculated. Four cases need to be considered:

- (old value > new value) AND (old value - new value) < max./2 -> use decrement operation;
- (old value < new value) AND (new value - old value) < max./2 -> use increment operation;
- (old value > new value) AND (old value - new value) >= max./2 -> use increment operation; and

- d. (old value < new value) AND (new value - old value) \geq max./2 -> use decrement operation.

The maximum value (max.) is as follows: 782 for VC-4 / VC-4-Xc, 764 for VC-3, 427 for VC-2, 139 for VC-12 and 103 for VC-11.

5 The pointer generation and insertion in the TC Adaptation part of the TCM Source function block inserts stuffing actions every 8th virtual container frame. Using this stuffing rate (and assuming that the incoming pointer value does not drift), the time to reach the incoming pointer is:

- 392 milliseconds for VC-4 / VC-4-Xc
- 10 • 383 milliseconds for VC-3
- 856 milliseconds for VC-2
- 280 milliseconds for VC-12
- 208 milliseconds for VC-11

15 This time may be lengthened by up to 10% if the incoming pointer value drifts with the maximum offset defined for SDH signals.

If a further frame offset discontinuity occurs while the TC Adaptation part of the TCM Source function block is in the smooth pointer adaptation mode, the distance calculation is retriggered. In this case, the distance between the currently inserted pointer and the new pointer, after the frame offset discontinuity, is calculated and the adaptation is restarted.

20 During the smooth pointer adaptation period the virtual container is overwritten by an all-ones signal (VC-AIS) in the Adaptation part of the TCM Source function block and Incoming AIS is signalled via N1/N2.

25 If a SSF condition occurs while the smooth pointer adaptation mode is active, the holdover mode is entered using the previously inserted pointer value.

As soon as the inserted pointer value is equal to the incoming one, a pointer check mode is entered as follows:

- If the inserted pointer is the same as the incoming one for three consecutive times, the insertion is switched off and the incoming pointer is directly passed to the output;
- 30 • If a new pointer value is detected at the input (most likely an increment /

decrement operation), the smooth pointer adaptation mode is entered again to follow the change of the pointer value.

With the end of the smooth pointer adaptation the all-ones insertion for the virtual container and the signalling of Incoming AIS via N1/N2 is stopped.

5 **Frame Offset Discontinuity Inband Signalling Mechanism**

Block diagrams for the Frame Offset Discontinuity (FOD) inband signalling mechanism are given for the TCM Source function block in Figure 5 and for the TCM Sink and TCM NIM function block in Figure 6.

Operation of the TCM Source Function Block for VC-4, VC-4-Xc and VC-3

10 **TC Trails**

After the detection of the frame offset discontinuity, the frame offset discontinuity is signalled into the TC trail by setting bits b1..b4 of byte N1 (IEC = Incoming Error Count) to 1101 for 6 consecutive virtual container frames. This value is normally not used and according to the standard (EN 300 417-4-1) it is interpreted in the TC NIM TT Sink function and in the TC TT Sink function as 0 BIP violations. During the signalling period, the last valid received pointer is inserted (holdover mode). The period of signalling lasts 6 * 125 us. In order not to misinterpret the incoming BIP-8 violations of the path segment in front of the TC trail as bit errors of the tandem connection trail itself, the BIP-8 value calculated over the previous ingressing frame is inserted at the position of the incoming B3 byte. After this correction the normal processing of the TC TT Source function (i.e. N1 modification and B3 compensation, see EN 300 417-4-1) is carried out. To replace the incoming B3 byte by the BIP-8 value calculated by the TC TT Source part of the TCM Source function block is not a problem as due to the frame offset discontinuity the byte accessed as "B3" is more than likely not the BIP-8 value originally inserted at the begin of the path. After the end of the signalling phase the holdover mode for the pointer is left and the ingressing pointer is passed through transparently.

Operation of the TCM Sink and TCM NIM Function Block for VC-4, VC-4-Xc, and VC-3 TC Trails

The frame offset discontinuity detection process at the sink function monitors bits b1..b4 of byte N1. If the reserved value 1101 is received in 3 consecutive virtual container frames the TCM Sink and TCM NIM function blocks will enter the "frame offset discontinuity suspension state". If there is no retriggering the suspension state will be left

with the next but one 1-second tick. So the duration of the suspension state is at least one second. (A central one second tick is available in the system which e.g. is also used for performance monitoring purpose). However, if a SSF condition is detected during the FOD suspension state, the FOD suspension state will immediately be left and normal operation will be re-established. The transition into the FOD suspension state is reported towards the network element management system.

Operation of the TCM Source Function Block for VC-2, VC-12, VC-11 TC Trails

After the detection of the frame offset discontinuity, the frame offset discontinuity is signalled into the tandem connection trail by inserting the alternating pattern 01, 10 into bits b3, b4 of byte N2 for 7 consecutive VC-2 / VC-12 / VC-11 frames. Bit b3 is normally fixed to 1, and b4 indicates Incoming AIS. During the signalling period, the last valid received pointer is inserted (holdover mode). The period of signalling lasts 7 * 500 us. After the end of the signalling phase the holdover mode for the pointer is left and the ingressing pointer is passed through transparently.

Operation of the TCM Sink and TCM NIM Function Block for VC-2, VC-12, VC-11 TC Trails

The frame offset discontinuity detection process at the sink function monitors bits b3, b4 of byte N2. If the reserved pattern sequence 01, 10, 01 is received (this will take 3 VC frames) the TCM Sink and TCM NIM function block will enter the "frame offset discontinuity suspension state". If there is no retriggering the suspension state will be left with the next but one 1-second tick. So the duration of the suspension state is at least one second. (A central one second tick is available in the system which e.g. is also used for performance monitoring purpose). However, if an SSF is detected during the FOD suspension state, the FOD suspension state will immediately be left and normal operation will be re-established. The transition into the FOD suspension state is reported towards the network element management system.

Operation during the Frame Offset Discontinuity Suspension State

In principle, three requirements have to be fulfilled by the TCM Sink function block and the TCM NIM function block:

- Do not extend the interruption of the signal;

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- Suppress all effects of the frame offset discontinuity for the fault management and performance monitoring; and
- Do not use tandem connection defect condition changes for SNCP switching.

Handling of Defects

5 In order to minimize the signal interruption the defect detection processes are not affected by the frame offset discontinuity suspension state, i.e. it cannot be ruled out that defects are detected during the phase of misalignment between pointer and transported signal. However there is a modified processing of the defects and performance monitoring primitives during the frame offset discontinuity suspension state. For this purpose the state of the tandem connection defects dUNEQ, dLTC, dTIM, dDEG, dRDI, dODI, dIncAIS is frozen with the transition into the frame offset discontinuity suspension state. The frozen versions of these tandem connection defects are called dUNEQ', dLTC', dTIM', dDEG', dRDI', dODI', dIncAIS' and are made available as latched copies for further processing (consequent action handling, defect correlation, performance monitoring). However this additional latching of the tandem connection defects does not suspend the tandem connection defect detection processes. The freeze of the defects is shown for example by the block diagram of Figure 7. The defect storage becomes transparent when the FOD suspension state is inactive.

20 The relations below are valid in case that CI_SSF is inactive, otherwise the FOD suspension state is left. The relations are quite similar to those used in the normal operation state, however partially the frozen versions of the tandem connection defects are used in the FOD suspension state.

Detection of Bit Errors

25 The detection of nN_B, nON_B, nF_B, nOF_B is stopped during the frame offset discontinuity suspension phase.

Consequent Actions

The following modified consequent action handling is used during the frame offset discontinuity suspension state:

30 aAIS <- dUNEQ or dTIM or dLTC
aTSF <- CI_SSF or dUNEQ' or dTIM' or dLTC'
aTSD <- dDEG'

```

aRDI  <- CI_SSF or dUNEQ' or dTIM' or dLTC'
aREI  <- nN_B
aODI  <- CI_SSF or dUNEQ' or dTIM' or dLTC' or dIncAIS'
aOEI  <- nON_B
5    aOSF <- CI_SSF or dUNEQ or dTIM or dLTC or dIncAIS

```

Rationales:

- aAIS and aOSF are used for insertion of AIS in the TC TT Sink and TC Adaptation Sink function. As the egressing signal shall not be interrupted for a fixed time but shall recover as soon as possible, the actually detected defects are used here.
- aTSF and aTSD are used as switching criteria for TC NIM TT based SNCP. As there shall be no protection switches caused by incorrectly detected tandem connection defects during the frame offset discontinuity suspension state, the frozen tandem connection defects are used here.
- aTSF is also used for detection of defect seconds pN_DS. Also here the frozen states of the tandem connection defects shall be used.
- aRDI is used for insertion of the corresponding remote information into the reverse direction. To get a consistent view to the performance monitoring it should be identical with aTSF which is used for pN_DS, therefore also here the frozen states of the tandem connection defects are used.
- aODI is used for insertion of the corresponding remote information into the reverse direction and for detection of defect seconds pON_DS. Also here the frozen states of the tandem connection defects are used.
- aREI and aOEI will not indicate errors towards the remote end as the detection of bit errors is stopped during the frame offset discontinuity suspension state.

Defect Correlations

The following modified defect correlations are used during the frame offset discontinuity suspension state:

```

cUNEQ    <- MON and dUNEQ'
30    cLTC  <- MON and (not CI_SSF) and (not dUNEQ') and dLTC'
        cTIM  <- MON and (not dUNEQ') and (not dLTC') and dTIM'

```


cDEG <- MON and (not dTIM') and (not dLTC') and dDEG'
 cSSF <- MON and CI_SSF and SSF_reported
 cRDI <- MON and (not dUNEQ') and (not dTIM') and (not dLTC') and dRDI'
 and RDI_Reported
 5 cODI <- MON and (not dUNEQ') and (not dTIM') and (not dLTC') and dODI'
 and ODI_Reported
 cIncAIS <- MON and (not CI_SSF) and (not dTIM') and (not dLTC') and
 dIncAIS' and IncAIS_Reported.

10 **Rationale:**

- The frozen states of the tandem connection defects are used for the defect correlation. So also the reporting of the faults will be frozen during the frame offset discontinuity suspension state.

Performance Monitoring

15 The following modified determination of the performance monitoring primitives is used during the frame offset discontinuity suspension state.

pN_DS <- aTSF or dEQ
 pF_DS <- dRDI'
 pN_EBC <- □nN_B
 20 pF_EBC <- □nF_B
 pON_DS <- aODI or dEQ
 pOF_DS <- dODI'
 pON_EBC <- □nON_B
 pOF_EBC <- □nOF_B

25 **Rationales:**

- The accumulation of bit errors during the frame offset discontinuity suspension state is suspended as the detection of bit errors is stopped in this state.
 - For the detection of defect seconds the frozen states of the tandem connection defects are used, therefore also the defect second detection is frozen during this period.
- 30

**Detection and Compensation of Ingressing Frame Offset Discontinuities for
Tandem Connection Trails**

Abstract of the Disclosure

5 A method and system are provided for the detection and compensation of
frame offset discontinuities for tandem connection trails in general and especially to
frame offset discontinuities occurring at the entrance of a network element in a
Synchronous Digital Hierarchy (SDH) and Synchronous Optical Network (SONET)
system. More specifically, a method of transmitting data in a synchronous hierarchic
10 network system comprising at least a path segment between a first network element
and at least a second network element on which tandem connection monitoring (TC)
method is established for monitoring transmission of information over the path
segment is characterised by detection of frame offset discontinuities at the first
network element on the basis of the detection of an alteration of the pointer value.

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**Detection and Compensation of Ingressing Frame Offset Discontinuities for
Tandem Connection Trails**

Abstract of the Disclosure

5 [The invention relates to] A method and system are provided for the detection
and compensation of frame offset discontinuities for tandem connection trails in
general and especially to frame offset discontinuities occurring at the entrance of a
network element in a Synchronous Digital Hierarchy (SDH) and Synchronous Optical
Network (SONET) system. [It is an object of the invention therefore, to reduce the
10 influence of frame offset discontinuities occurring at the beginning of a Tandem
Connection Trail in a Synchronous Digital Hierarchy (SDH) or in a Synchronous Opti-
cal Network (SONET) System. This problem is solved by] More specifically, a
method of transmitting data in a synchronous hierarchic network system comprising
at least a path segment between a first network element [(A)] and at least a second
15 network element [(B)] on which tandem connection monitoring (TC) method is
established for monitoring transmission of information over [said] the path segment[.
The method] is characterised by detection of frame offset discontinuities at [said] the
first network element [(A)] on the basis of the detection of an alteration of the pointer
value.
20 [Figure 3]

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[Lucent (UK) Technologies]

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**Detection and Compensation of Ingressing Frame Offset Discontinuities for
Tandem Connection Trails**

Technical Field [Description]

5 The invention relates to the detection and compensation of frame offset discontinuities for tandem connection trails in general and especially to frame offset discontinuities occurring at the entrance of a network element in a Synchronous Digital Hierarchy (SDH) and Synchronous Optical Network (SONET) system.

10 **Background of the Invention**

 The problem addressed with this invention typically arises in Synchronous Digital Hierarchy (SDH) and Synchronous Optical Network (SONET) systems in the case of switching of parts of a network path due to a failure condition or in case of a faulty or defect part of the network path. For a deeper understanding of SDH and SONET systems, reference is made to "Understanding of SONET/SDH", ISBN 0-9650448-2-3, Andan Publisher, New Jersey. In the before-mentioned network systems a tandem connection is intended to provide an administrative monitoring domain which is operating independent of the end to end path. Errors and faults outside the tandem connection should not be noticed in the tandem connection performance monitoring and fault management itself. However, the existing tandem connection equipment specifications in ETSI EN300 417-4-1 and ITU-T G.783 do not support this independence under all conditions especially if frame offset discontinuities occur. A frame offset discontinuity is a change of the pointer's value which defines the flexible start position of the Virtual Container within the SDH frame or an overflow or underflow of the elastic store used to adapt the ingressing data stream to the system frequency. Pointer justifications (i.e. increment and decrement operations) also change the value of the pointer but they are not frame offset discontinuities in the sense of or according to the definition as used in connection with this invention.

 On every incoming frame offset discontinuity of the Virtual Container (VC) within the SDH frame, the tandem connection performance monitoring system will detect errored blocks and therefore declare one or two errored seconds (during which data are declared to be faulty or errored). Also Tandem Connection (TC) alarms may be raised.

These undesirable effects are caused by the fact that Pointer Processors (PP) are used in the network elements for the adaptation of the frequency of the incoming signal to the internal frequency of the network element and for accessing the virtual containers.

The transport of frame offset discontinuities through the network (series of pointer processors) will be fast (few bytes delay per Pointer Processor) in the virtual container signal, and much slower in the Administrative Unit (AU) or Tributary Unit (TU) (0 to 1 frame delay per pointer processor). For a certain amount of time the frame start indication, i.e. the pointer at the tandem connection sink node is not aligned with the actual phase of the virtual container. Information will be read from the wrong byte positions during this period of misalignment. This effect increases with the number of pointer processors in the chain.

The problem for tandem connection trails is introduced by the fact that there is no separate layer to transport the tandem connection information and that the path (virtual container) layer is used instead. Therefore interruptions on the path (virtual container) layer also influence the tandem connection layer.

Summary of the Invention

[It is an object of the invention therefore, to reduce] According to the principles of the invention, the influence of frame offset discontinuities occurring at the beginning of a Tandem Connection Trail in a Synchronous Digital Hierarchy (SDH) or in a Synchronous Optical Network (SONET) System is reduced.

[The invention is defined in independent claims 1 and 15.]

[Based on the invention,] More specifically, frame offset discontinuities are detected and relayed to a network management system where this information is further utilized to initiate predefined process steps.

In [a preferred] one illustrative embodiment of the invention, the signalled information is processed and stored as a kind of transmission quality protocol for a segment of the respective network path provided to a customer. As a consequence thereof, a network provider is enabled to show that the distortion or the fault condition was not caused within the providers network path segment but was received at the entrance or input of the path segment.

If the discontinuity condition detected at network element A is transmitted to network element B, which process also is termed throughout the description of the invention as "frame offset discontinuity inband signalling", then a provider may collect this information for establishing a transmission quality report and filter out faulty or distorted periods of transmission. In addition, storing of the quality data will reveal at any later point of time that, even if certain incoming data were faulty, these data were transmitted essentially without additional distortions along the providers network path segment.

In another [preferred] illustrative embodiment, after detection of a discontinuity condition, transmitted pointer values are altered stepwise towards a new valid pointer value (i.e. a valid value after occurrence of the offset discontinuity). Due to the stepwise alteration an uninterrupted or contiguous adaptation from an early undistorted transmission condition to a new undisturbed transmission condition for the TC-relevant data is obtained for the downstream network elements. This adaptation is also named a "smooth" pointer adaptation in the course of the further detailed description.

Advantageously, faster smooth adaptation can be obtained if the distance between the last valid pointer value before and the new valid pointer value after the detected discontinuity condition is used to evaluate and select the shortest difference for the stepwise adaptation of the pointer values.

In [a further preferred] another illustrative embodiment of the invention, the pointer values of a pointer, as received in advance of the discontinuity condition, are transmitted during the time interval used to evaluate the necessary pointer actions (in case of smooth pointer adaptation) or to signal the discontinuity (in case of inband signalling) to avoid transmitting of faulty TC-relevant data during this time interval.

If, after detection and signalling of the discontinuity condition, the tandem connection monitoring (TC) system suspends counting and evaluating of errors and failures for a predefined interval of time and this interval of time is chosen to be sufficient for covering the period of time necessary for compensating the discontinuity condition, suspending is of no negative influence but beneficial as it is not desired to report any TC failures and errors caused by the ingressing discontinuity.

Moreover, in case that after detection of the discontinuity condition, collection or reporting of errors and failures is interrupted for a predefined interval of time and this

interval of time is chosen to be long enough for covering the period of time necessary for compensating the discontinuity condition, it is ascertained that a provider receives only undistorted TC-relevant data. It is assumed that the necessary interval of time during which the data transmission fails is within the allowed range for the relevant network applications.

Brief Description of the Drawings

The invention is described in more detail in connection with the appended drawings [and in view of preferred embodiments] in which:

Fig. 1 shows the functional model for a VC-4 path from Network Domain I via Network Domain II to Network Domain III with an embedded VC-4 tandem connection trail in Network Domain II between Network Elements (NE) A and B;

Fig. 2 details a High-Level View of [the Lucent PHASE] an exemplary SDH System Architecture;

Fig. 3 shows a block overview of a smooth pointer adaptation at the TCM Source Function Block;

Fig. 4 explains different cases for a pointer distance calculation for the smooth pointer adaptation mode;

Fig. 5 shows a block overview of frame offset discontinuity inband signalling at the TCM Source Function Block;

Fig. 6 shows a block overview of frame offset discontinuity signalling at the TCM Sink and TCM NIM function block; and

Fig. 7 shows a freeze process for TCM Sink and TCM NIM Defect Evaluation[;].

Detailed Description

Language, terminology and definitions are used throughout the description and in the claims in accordance to the respective international and national standard notation, i.e. unless other definitions were made in view of specific terms.

[Definitions and Glossary] Definitions and Glossary

In addition to definitions given in the introductory portion of the description, a synchronous hierarchic system according to the invention is an SDH or SONET system or a system including path sections between network elements NE including the

essential features of SDH or SONET systems.

The term "frame offset discontinuity" in connection with the invention is intended to cover an alteration of the pointer value other than an increment or decrement operation that is introduced by the network system and an ingressing discontinuity is meant to cover a discontinuity received by or entering a network element NE.

Even if in the following description of the most preferred embodiments only an SDH application is described, the essential principle is also applicable to SONET systems.

Figure 1 shows the functional model for a VC-4 path from Network Domain I via Network Domain II to Network Domain III with an embedded VC-4 tandem connection trail in Network Domain II between Network Elements (NE) A and B. The network elements (NEs) A and B are connected via an optical STM-1 link and both NEs are connected to Network Domain I and III via an optical STM-4 link.

The standards define that in NE A a pointer interpreter is in the adaptation sink function MS4/S4 and a pointer generator in the adaptation source function MS1/S4 with the Tandem Connection Adaptation Source S4D/S4 function and the TC TT Source S4D function between. For the reverse direction there is a pointer interpreter in the adaptation sink function MS1/S4 and a pointer generator in the adaptation source function MS4/S4 with the TC Adaptation Sink function S4D/S4 and the TC TT Sink function S4D between. In principle the same applies for NE B. The following mechanism is used at the TC Adaptation Source function on the transition into an SSF condition (holdover mode): The adaptation sink function MS4/S4 receives a signal with incorrect pointer values. It will count the number for some frames (3 if AIS in pointer, 8 if invalid pointer). During this period the frame start signal CI FS is maintained and the SSF indication signal CI SSF is inactive (=FALSE). On detection of a defect (dAIS or dLOP), CI_FS becomes invalid and CI_SSF becomes active (=TRUE). Furthermore, all-1's is inserted into the VC-4 signal. The TC Adaptation Source function S4D/S4 detecting the change in CI FS and CI SSF, enters "holdover" state in its Frame Start circuit, and continues to generate the frame start signal AI FS at the same position as before. It will also activate the signal fail indication signal AI SF.

The TC Trail Termination Source function S4D will continue to receive a valid AI FS signal at the same position as before. It will also receive an active AI SF signal and

will insert the IncAIS Code ($N1[1-4]=1110$) into the signal. Signalling of IncAIS must not start before the mismatch between B3 and the BIP-8 calculated over the previous frame (caused by the start of the all-ones-insertion) is cleared, i.e. not before a complete frame has been overwritten with all-ones. This is not explicitly described in the standards, but is essential to prevent the detection of TC bit errors at the far end. Therefore this procedure is considered as state of the art and is not further mentioned in the following text. The IncAIS code point in the IEC (=Incoming Error Code) field is interpreted as zero errors at the far end, which is correct for the transmission of VC-AIS. During the defect detection time in the adaptation sink function MS4/S4, mismatches between calculated BIP-8 and B3 will be detected as there is an access to a random B3 byte position. They are correctly encoded into the IEC field. As such, the transition will not result in the detection of any errors in the TC. The adaptation source function MS1/S4 receives a continuous CI FS and will not change its pointer value.

In principle an arbitrary frame start discontinuity can also be detected as a change of the frame start signal CI FS entering the TC Adaptation Source function S4D/S4.

However many implementations do not follow the standards with respect to the locations of the pointer interpreter and the pointer generator, but have a combined pointer interpreter/generator in the adaptation sink function MSx/ S4 and no further pointer handling in the adaptation source function MSx/S4. Therefore a frame offset discontinuity entering the network element with the TC Adaptation Source function is not always accompanied by a new data flag (NDF) in the pointer. Following this kind of implementation also means that the TC Adaptation Source function S4D/S4 must have the functionality of pointer generation in case of SSF (holdover mode).

Scenarios which cause frame offset discontinuities in the network in front of the TC Adaptation Source are listed below. It is also shown which resulting pointer transitions are input to the NE with the TC Adaptation Source function:

- Recovery from Server Signal Fail (SSF) condition (Loss of Pointer (LOP)/AU/TU-AIS) as a result of the repair of a fault or of a protection switch (initiated by a SSF condition)

In this case, the pointer transitions are:

- SSF -> New Data Flag (NDF) -> Norm
- SSF -> Norm

- Establishment of a different path as a result of a crossconnect change in front of the tandem connection trail. In this case, the pointer transitions are (this also includes signal changes where typically an Unequipped Signal is used):

- Norm1 -> NDF -> Norm2
- Norm1 -> Norm2

- Change of phase alignment of byte-synchronously mapped plesiochronous signals. (An example is described in EN 300 417-4-1, Annex C.). In this case, the pointer transitions are:

- Norm1 -> NDF -> Norm2

- Protection switches caused by external commands (manual or forced switch), by revertive operation mode or by condition changes which do not affect the pointer (e.g. Signal Degrade). In this case, the pointer transitions are:

- Norm1 -> NDF -> Norm2
- Norm1 -> Norm2

The transition from a valid signal into SSF is also a frame offset discontinuity. As this case is considered already in the standards ("Holdover mode for the TC Adaptation Source function") it is not an issue of the further discussion.

[1. Inventive Problem Solution]

To solve the problem, frame offset discontinuities need to be detected at the TC Adaptation Source function. After detection, either an error free tandem connection signal can be inserted at the TC Trail Termination Source function or the frame offset discontinuity can be communicated to the TC Trail Termination Sink function and TC Non-intrusive Trail Termination Sink function to suspend the performance monitoring and the evaluation of the tandem connection defects there for an appropriate period of time.

[2.1_] Frame Offset Discontinuity Detection

An incoming frame offset discontinuity occurs if a pointer value is received different from the previous one with NDF set or if three consecutive new, valid and identical pointer values are received without NDF set. Normal stuffing actions are not frame offset discontinuities.

Therefore the detection of the frame offset discontinuity can be achieved by searching for both:

- the New Data Flag enabled in the incoming pointer; and
- three times detection of a new pointer value without NDF (New Pointer Value (NPV)).

The pointer transitions that need to be detected are shown in EN 300 417-1-1, Annex B. Figure B1 in this annex shows the pointer interpretation states. All states marked with "NDF_enable" or "3*new_point" are frame offset discontinuities as described above.

[2.2_] Procedures to Compensate the Effects of Ingressing Frame Offset Discontinuities

To improve the behaviour of tandem connection trails with respect to ingressing frame offset discontinuities it is intended according to the invention to:

- suppress the propagation of frame offset discontinuities into the tandem connection trail by converting the frame offset discontinuities to series of pointer justifications;
- signal the incoming frame offset discontinuity to the TC Trail Termination (TC TT) Sink function and TC Non-intrusive Trail Termination (TC NIM TT) Sink functions and suspend counting and reporting of errors and defects there for a certain period of time; and
- signal the detected frame offset discontinuity to the network element management and network management system for further processing. (The reporting is done towards the Equipment Management Function (EMF) and then e.g. via the Q-interface to the network element management system.)

[2.2.1 FIRST PREFERRED EMBODIMENT,] Smooth Pointer Adaptation

The frame offset discontinuity within the tandem connection trail can be completely suppressed by changing the pointer generation in the Network Element containing the TC Adaptation Source. The idea is to "smooth" the frame offset discontinuity by converting it to a series of consequent pointer actions (increment or decrement) instead of following the jump immediately.

In a first option the distance of the old and new pointer is not taken into account to choose the shortest way of adaptation, but either a sequence of positive or negative justifications is used to go from the last valid pointer value to the new pointer value.

In a second option in order to keep the recovery time for this method as short as possible, the distance between the last valid pointer value and the new valid value after the frame offset discontinuity shall be evaluated. Depending on the distance, either positive or negative justifications shall be used to go from the old pointer value to the new pointer value. During the distance evaluation the last valid pointer value shall be inserted (holdover mode).

As a further enhancement (third option) the drift direction of the incoming pointer may be evaluated and used for the decision which stuffing direction should be used. This enhancement can be used if the distance for positive and negative justifications is nearly equal.

After the stuffing direction is decided, the pointer generator at the Tandem Connection Monitoring (TCM) source starts inserting pointer justifications. The justification rate shall be as high as feasible but low enough so that it can be propagated through the tandem connection trail without introducing pointer errors.

As soon as the pointer insertion reaches the same pointer value as the incoming signal, a check of the inserted pointer versus the incoming pointer sequence is necessary. If the inserted pointer value is at least three times identical to the incoming pointer, the insertion can be switched off. This check is necessary to prevent the creation of invalid pointer sequences (only every four frames pointer justifications are allowed).

As an option to reduce induced errors behind the tandem connection trail, Incoming AIS (IncAIS) may be signalled via N1/N2 and VC-AIS may be inserted in the path while the smooth pointer adaptation is active. For example such errors would occur if a desynchroniser process accesses random byte positions to detect stuffing

information. This could put it beyond its phase adjustment limits.

According to this method, the frame offset discontinuity must not be propagated into the tandem connection trail during the detection period of the frame offset discontinuity (i.e. until the smooth pointer adaptation starts).

- 5 A major advantage of this method is the fact that it requires only modifications at the TC Adaptation Source. This would allow interworking with all equipment containing a standard-compliant TC TT Sink function or TC NIM TT Sink function.

[2.2.2_ SECOND PREFERRED EMBODIMENT,] Frame Offset Discontinuity Inband Signalling

- 10 The idea of the method of frame offset discontinuity (FOD) inband signalling is to delay the incoming frame offset discontinuity by introducing a holdover mode by a few virtual container frames so that the appearance of a frame offset discontinuity can be communicated within the tandem connection trail from the TC Adaptation Source function to the TC TT Sink function and intermediate TC NIM TT Sink functions.

- 15 After detection of the frame offset discontinuity, the pointer generation of the Network Element containing the tandem connection source function shall continue to transmit the pointer value used before the frame offset discontinuity (holdover mode). This is similar to the method used for the transition into SSF.

- 20 During the holdover time, a signalling code is inserted in the Tandem Connection Path Overhead (i.e. N1 for VC-4/3 and contiguous concatenated VC-4-Xc TC, N2 for VC-2/12/11 TC). This code must be selected such that it is not used during normal tandem connection operation and it should be selected such that the operation of Performance Monitoring and Fault Management is not disturbed. For VC-4/3 and VC-4-Xc TC, a correction of the B3 byte may be necessary, depending on the inserted signalling code.

- 25 To keep the holdover phase as short as possible it is recommended to use N1/N2 bits repeated every VC-frame (i.e. bits within the 76 frames tandem connection multiframe should not be used).

- 30 The signalling sequence shall be such that a safe transmission even with up to one bit error in the sequence is possible. After the frame offset discontinuity is signalled, the frame offset discontinuity can be propagated into the tandem connection trail.

An alternative option when doing this is not to immediately switch over to the new pointer value after the end of the signalling sequence, but instead to take care that a correct sequence of pointer values is maintained.

At the TC TT Sink function, the frame offset discontinuity code shall be detected
5 out of the N1/N2 bytes. The detection shall tolerate at least one bit error in the signalling code.

After reception of the frame offset discontinuity code, the signal can be assumed as defective for a fixed period of time. During this period, the TC TT Sink function and TC NIM TT Sink function shall stop the accumulation of errors and suspend the usage of
10 tandem connection defects for fault processing and defect second detection. Furthermore, the TC NIM TT Sink function shall suspend the usage of tandem connection defects for sub network connection protection (SNCP) switching.

For this method, the frame offset discontinuity must not be propagated into the TC trail until it is completely signalled.

15 [2.2.3_] Frame Offset Discontinuity Reporting

The reporting of frame offset discontinuities can be done directly at the TC Adaptation Source function or (with FOD inband signalling as described above) at the TC TT Sink function or TC NIM TT Sink function.

The reported frame offset discontinuities can be used for event logging or
20 performance monitoring.

[3.] Application Example

In the TCM application, the described compensation modes can be activated and used separately per tandem connection trail. So by means of the network element or network management system each tandem connection trail can be adapted to the needs
25 of the planned network application. If the compensation modes are disabled, the TCM function behaves as required by the current standards. The third mechanism, to report the detected incoming frame offset discontinuities, is implemented in parallel.

In the application example the functionality of the TC Adaptation Source function and of the TC TT Source function is implemented by the TCM Source function block,
30 that of the TC Adaptation Sink function and of the TC TT Sink function by the TCM Sink

function block and that of the TC NIM TT Sink function by that of the TC NIM function block.

[3.1_] Frame Offset Discontinuity Detection

This part is common for all proposed mechanisms. The [Goal] goal of the frame offset discontinuity detection is to detect all incoming frame offset discontinuities. As stated above, the pointer transitions that need to be detected are shown in EN 300 417-1-1, Annex B. Figure B1 in this annex shows the pointer interpretation states. All states marked with "NDF_enable" or "3*new_point" are frame offset discontinuities.

In one exemplary SDH system manufactured by [the] Lucent Technologies, [PHASE System Family] a pointer processing unit is located in front of the TCM Source function block. The described application relies on the fact that the frame offset discontinuities are detected in the pointer processor unit so that only valid pointers or AU/TU-AIS conditions arrive at the TCM Source function block. The high level view of [the Lucent PHASE] this exemplary system architecture is given by Figure 2 .

The table below shows how incoming frame offset discontinuities are converted by the pointer processor unit in front of the TCM Source function block.

| Input to PP Unit: Transition | Input to PP Unit: Condition | Input to TCM Source function block: Pointer sequence generated at PP Unit |
|---------------------------------|--------------------------------|--|
| INC -> NDF | NDF_enable set | Norm -> NDF_enable -> Norm |
| DEC -> NDF | NDF_enable set | Norm -> NDF_enable -> Norm |
| NDF -> NDF | NDF_enable set | Norm -> NDF_enable -> Norm |
| Norm -> NDF | NDF_enable set | Norm -> NDF_enable -> Norm |
| AIS -> NDF | NDF_enable set | AU/TU-AIS -> NDF_enable -> Norm |
| Norm -> Norm | 3*new_point | Norm -> NDF_enable -> Norm |
| INC -> Norm | 3*new_point | Norm -> NDF_enable -> Norm |
| DEC -> Norm | 3*new_point | Norm -> NDF_enable -> Norm |
| NDF -> Norm | 3*new_point | Norm -> NDF_enable -> Norm |
| LOP -> Norm | 3*new_point | AU/TU-AIS -> NDF_enable -> Norm |
| AIS -> Norm | 3*new_point | AU/TU-AIS -> NDF_enable -> Norm |

Looking at the generated pointer sequences in the table above it can be seen that all incoming frame offset discontinuities arrive at the TCM Source function block as

a pointer with the NDF_enable set. However, there may be some older equipment which doesn't generate NDF while going from AU/TU-AIS to Norm.

Therefore the conditions that need to be detected at the TCM Source function block are:

- 5 • NDF_enable
- Transition AIS -> Non-AIS

For this detection, it is sufficient to check the H1/V1 byte for the following conditions:

- 10 • NDF_enable, i.e. NDF-bits in H1/V1 set to "1001". It is not necessary to check for the other valid NDF_enable values, the ss-bit match and the pointer offset value because the transmission from pointer processor unit to TCM source function is system-internal and can be assumed as error-free[.]; and
- 15 • Transition from an "all-ones" in H1/V1 to any other value to detect the AU/TU-AIS to Non-AIS transition in case of missing NDF (interworking with old pointer processor units which might not generate an NDF).

The two conditions above are detected by a simple one-time pattern match check of the incoming H1/V1 byte per virtual container at the TCM Source function block. The detected frame offset discontinuities are made available for reporting towards the network element management.

20 **[3.2_] Smooth Pointer Adaptation**

For the smooth pointer adaptation a pointer interpreter and pointer generator with only limited functionality (regarded to what's required in the standards) is implemented. Figure 3 shows a block diagram of the smooth pointer adaptation mechanism at the TCM Source function block.

- 25 The pointer interpreter at the TC Adaptation Source function always stores the last valid pointer value. This can be either the last pointer value before entering SSF (if the TC Trail Adaptation Source goes in holdover mode) or the pointer value contained in the AU/TU frame before the frame offset discontinuity. During the smooth pointer adaptation phase, the stored received pointer value is
- 30 replaced by the last inserted pointer value. At the occurrence of a frame offset

discontinuity, this pointer value is communicated to the TC Adaptation part of TCM Source function block where it is inserted into the outgoing pointer.

As soon as a new valid pointer is available (i.e. directly after the frame offset discontinuity), the pointer distance between the new valid pointer and the stored pointer value is measured to decide the stuffing direction for the inserted pointer.

Figure 4 shows how the pointer distance is calculated. Four cases need to be considered:

- a. (old value > new value) AND (old value - new value) < max./2 -> use decrement operation;
- 10 b. (old value < new value) AND (new value - old value) < max./2 -> use increment operation;
- c. (old value > new value) AND (old value - new value) >= max./2 -> use increment operation; and
- 15 d. (old value < new value) AND (new value - old value) >= max./2 -> use decrement operation.

The maximum value (max.) is as follows: 782 for VC-4 / VC-4-Xc, 764 for VC-3, 427 for VC-2, 139 for VC-12 and 103 for VC-11.

The pointer generation and insertion in the TC Adaptation part of the TCM Source function block inserts stuffing actions every 8th virtual container frame. Using this stuffing rate (and assuming that the incoming pointer value does not drift), the time to reach the incoming pointer is:

- 392 milliseconds for VC-4 / VC-4-Xc
- 383 milliseconds for VC-3
- 856 milliseconds for VC-2
- 25 • 280 milliseconds for VC-12
- 208 milliseconds for VC-11

This time may be lengthened by up to 10% if the incoming pointer value drifts with the maximum offset defined for SDH signals.

If a further frame offset discontinuity occurs while the TC Adaptation part of the TCM Source function block is in the smooth pointer adaptation mode, the distance

calculation is retriggered. In this case, the distance between the currently inserted pointer and the new pointer, after the frame offset discontinuity, is calculated and the adaptation is restarted.

During the smooth pointer adaptation period the virtual container is overwritten
5 by an all-ones signal (VC-AIS) in the Adaptation part of the TCM Source function block and Incoming AIS is signalled via N1/N2.

If a SSF condition occurs while the smooth pointer adaptation mode is active, the holdover mode is entered using the previously inserted pointer value.

As soon as the inserted pointer value is equal to the incoming one, a pointer
10 check mode is entered[.] as follows:

- If the inserted pointer is the same as the incoming one for three consecutive times, the insertion is switched off and the incoming pointer is directly passed to the output[.];
- If a new pointer value is detected at the input (most likely an increment /
15 decrement operation), the smooth pointer adaptation mode is entered again to follow the change of the pointer value.

With the end of the smooth pointer adaptation the all-ones insertion for the virtual container and the signalling of Incoming AIS via N1/N2 is stopped.

[3.3_] Frame Offset Discontinuity Inband Signalling

20 [3.3.1_ Signalling] Mechanism

Block diagrams for the [FOD] Frame Offset Discontinuity (FOD) inband signalling mechanism are given for the TCM Source function block in Figure 5 and for the TCM Sink and TCM NIM function block in Figure 6.

25 [3.3.1.1_] Operation of the TCM Source Function Block for VC-4, VC-4-Xc and VC-3 TC Trails

After the detection of the frame offset discontinuity, the frame offset discontinuity is signalled into the TC trail by setting bits b1..b4 of byte N1 (IEC = Incoming Error Count) to 1101 for 6 consecutive virtual container frames. This value is normally not used and according to the standard (EN 300 417-4-1) it is interpreted in the TC NIM TT
30 Sink function and in the TC TT Sink function as 0 BIP violations. During the signalling

period, the last valid received pointer is inserted (holdover mode). The period of signalling lasts $6 * 125$ us. In order not to misinterpret the incoming BIP-8 violations of the path segment in front of the TC trail as bit errors of the tandem connection trail itself, the BIP-8 value calculated over the previous ingressing frame is inserted at the position of the incoming B3 byte. After this correction the normal processing of the TC TT Source function (i.e. N1 modification and B3 compensation, see EN 300 417-4-1) is carried out. To replace the incoming B3 byte by the BIP-8 value calculated by the TC TT Source part of the TCM Source function block is not a problem as due to the frame offset discontinuity the byte accessed as "B3" is more than likely not the BIP-8 value originally inserted at the begin of the path. After the end of the signalling phase the holdover mode for the pointer is left and the ingressing pointer is passed through transparently.

[3.3.1.2_] Operation of the TCM Sink and TCM NIM Function Block for VC-4, VC-4-Xc, and VC-3 TC Trails

The frame offset discontinuity detection process at the sink function monitors bits b1..b4 of byte N1. If the reserved value 1101 is received in 3 consecutive virtual container frames the TCM Sink and TCM NIM function blocks will enter the "frame offset discontinuity suspension state". If there is no retriggering the suspension state will be left with the next but one 1-second tick. So the duration of the suspension state is at least one second. (A central one second tick is available in the system which e.g. is also used for performance monitoring purpose). However, if a SSF condition is detected during the FOD suspension state, the FOD suspension state will immediately be left and normal operation will be re-established. The transition into the FOD suspension state is reported towards the network element management system.

[3.3.1.3_] Operation of the TCM Source Function Block for VC-2, VC-12, VC-11 TC Trails

After the detection of the frame offset discontinuity, the frame offset discontinuity is signalled into the tandem connection trail by inserting the alternating pattern 01, 10 into bits b3, b4 of byte N2 for 7 consecutive VC-2 / VC-12 / VC-11 frames. Bit b3 is normally fixed to 1, and b4 indicates Incoming AIS. During the signalling period, the last valid received pointer is inserted (holdover mode). The period of signalling lasts $7 * 500$ us. After the end of the signalling phase the holdover mode for the pointer is left and the ingressing pointer is passed through transparently.

[3.3.1.4_] Operation of the TCM Sink and TCM NIM Function Block for VC-2, VC-12, VC-11 TC Trails

The frame offset discontinuity detection process at the sink function monitors bits b3, b4 of byte N2. If the reserved pattern sequence 01, 10, 01 is received (this will take 3 VC frames) the TCM Sink and TCM NIM function block will enter the "frame offset discontinuity suspension state". If there is no retriggering the suspension state will be left with the next but one 1-second tick. So the duration of the suspension state is at least one second. (A central one second tick is available in the system which e.g. is also used for performance monitoring purpose). However, if an SSF is detected during the FOD suspension state, the FOD suspension state will immediately be left and normal operation will be re-established. The transition into the FOD suspension state is reported towards the network element management system.

[3.3.2_] Operation during the Frame Offset Discontinuity Suspension State

In principle, three requirements have to be fulfilled by the TCM Sink function block and the TCM NIM function block:

- Do not extend the interruption of the signal;
- Suppress all effects of the frame offset discontinuity for the fault management and performance monitoring; and
- Do not use tandem connection defect condition changes for SNCP switching.

[3.3.2.1_] Handling of Defects

In order to minimize the signal interruption the defect detection processes are not affected by the frame offset discontinuity suspension state, i.e. it cannot be ruled out that defects are detected during the phase of misalignment between pointer and transported signal. However there is a modified processing of the defects and performance monitoring primitives during the frame offset discontinuity suspension state. For this purpose the state of the tandem connection defects dUNEQ, dLTC, dTIM, dDEG, dRDI, dODI, dIncAIS is frozen with the transition into the frame offset discontinuity suspension state. The frozen versions of these tandem connection defects are called dUNEQ', dLTC', dTIM', dDEG', dRDI', dODI', dIncAIS' and are made available as latched copies for further processing (consequent action handling, defect correlation,

performance monitoring). However this additional latching of the tandem connection defects does not suspend the tandem connection defect detection processes. The freeze of the defects is shown for example by the block diagram of Figure 7 . The defect storage becomes transparent when the FOD suspension state is inactive.

5 The relations below are valid in case that CI_SSF is inactive, otherwise the FOD suspension state is left. The relations are quite similar to those used in the normal operation state, however partially the frozen versions of the tandem connection defects are used in the FOD suspension state.

[3.3.2.2] Detection of Bit Errors

10 The detection of nN_B, nON_B, nF_B, nOF_B is stopped during the frame offset discontinuity suspension phase.

[3.3.2.3] Consequent Actions[:]

The following modified consequent action handling is used during the frame offset discontinuity suspension state:

15 aAIS <- dUNEQ or dTIM or dLTC
 aTSF <- CI_SSF or dUNEQ' or dTIM' or dLTC'
 aTSD <- dDEG'
 aRDI <- CI_SSF or dUNEQ' or dTIM' or dLTC'
 aREI <- nN_B
 20 aODI <- CI_SSF or dUNEQ' or dTIM' or dLTC' or dIncAIS'
 aOEI <- nON_B
 aOSF <- CI_SSF or dUNEQ or dTIM or dLTC or dIncAIS

Rationales:

- aAIS and aOSF are used for insertion of AIS in the TC TT Sink and TC
 25 Adaptation Sink function. As the egressing signal shall not be interrupted for a fixed time but shall recover as soon as possible, the actually detected defects are used here.
- aTSF and aTSD are used as switching criteria for TC NIM TT based SNCP. As
 30 there shall be no protection switches caused by incorrectly detected tandem connection defects during the frame offset discontinuity suspension state, the frozen tandem connection defects are used here.

- aTSF is also used for detection of defect seconds pN_DS. Also here the frozen states of the tandem connection defects shall be used.
- aRDI is used for insertion of the corresponding remote information into the reverse direction. To get a consistent view to the performance monitoring it should be identical with aTSF which is used for pN_DS, therefore also here the frozen states of the tandem connection defects are used.
- aODI is used for insertion of the corresponding remote information into the reverse direction and for detection of defect seconds pON_DS. Also here the frozen states of the tandem connection defects are used.
- aREI and aOEI will not indicate errors towards the remote end as the detection of bit errors is stopped during the frame offset discontinuity suspension state.

[3.3.2.4_] Defect Correlations

The following modified defect correlations are used during the frame offset discontinuity suspension state:

```

cUNEQ      <- MON and dUNEQ'
cLTC       <- MON and (not CI_SSF) and (not dUNEQ') and dLTC'
cTIM       <- MON and (not dUNEQ') and (not dLTC') and dTIM'
cDEG       <- MON and (not dTIM') and (not dLTC') and dDEG'
cSSF       <- MON and CI_SSF and SSF_reported
cRDI       <- MON and (not dUNEQ') and (not dTIM') and (not dLTC') and dRDI'
            and RDI_Reported
cODI       <- MON and (not dUNEQ') and (not dTIM') and (not dLTC') and dODI'
            and ODI_Reported
cIncAIS    <- MON and (not CI_SSF) and (not dTIM') and (not dLTC') and
dIncAIS'   and IncAIS_Reported.

```

Rationale[s]:

- The frozen states of the tandem connection defects are used for the defect correlation. So also the reporting of the faults will be frozen during the frame offset discontinuity suspension state.

[3.3.2.5] Performance Monitoring

The following modified determination of the performance monitoring primitives is used during the frame offset discontinuity suspension state.

5 pN_DS <- aTSF or dEQ
 pF_DS <- dRDI'
 pN_EBC <- □nN_B
 pF_EBC <- □nF_B
 pON_DS <- aODI or dEQ
 pOF_DS <- dODI'
 10 pON_EBC <- □nON_B
 pOF_EBC <- □nOF_B

Rationales:

- The accumulation of bit errors during the frame offset discontinuity suspension state is suspended as the detection of bit errors is stopped in this state.
- 15 • For the detection of defect seconds the frozen states of the tandem connection defects are used, therefore also the defect second detection is frozen during this period.

Detection and Compensation of Ingressing Frame Offset
Discontinuities for Tandem Connection Trails

Description

5 The invention relates to the detection and compensation of
frame offset discontinuities for tandem connection trails
in general and especially to frame offset discontinuities
occurring at the entrance of a network element in a
Synchronous Digital Hierarchy (SDH) and Synchronous Optical
10 Network (SONET) system.

The problem addressed with this invention typically arises
in Synchronous Digital Hierarchy (SDH) and Synchronous
Optical Network (SONET) systems in the case of switching of
15 parts of a network path due to a failure condition or in
case of a faulty or defect part of the network path. For a
deeper understanding of SDH and SONET systems, reference is
made to "Understanding of SONET/SDH", ISBN 0-9650448-2-3,
Andan Publisher, New Jersey. In the before-mentioned
20 network systems a tandem connection is intended to provide
an administrative monitoring domain which is operating
independent of the end to end path. Errors and faults
outside the tandem connection should not be noticed in the
tandem connection performance monitoring and fault
25 management itself. However, the existing tandem connection
equipment specifications in ETSI EN300 417-4-1 and ITU-T
G.783 do not support this independence under all conditions
especially if frame offset discontinuities occur. A frame
offset discontinuity is a change of the pointer's value
30 which defines the flexible start position of the Virtual

Container within the SDH frame or an overflow or underflow of the elastic store used to adapt the ingressing data stream to the system frequency. Pointer justifications (i.e. increment and decrement operations) also change the value of the pointer but they are not frame offset discontinuities in the sense of or according to the definition as used in connection with this invention.

On every incoming frame offset discontinuity of the Virtual Container (VC) within the SDH frame, the tandem connection performance monitoring system will detect errored blocks and therefore declare one or two errored seconds (during which data are declared to be faulty or errored). Also Tandem Connection (TC) alarms may be raised.

These undesirable effects are caused by the fact that Pointer Processors (PP) are used in the network elements for the adaptation of the frequency of the incoming signal to the internal frequency of the network element and for accessing the virtual containers.

The transport of frame offset discontinuities through the network (series of pointer processors) will be fast (few bytes delay per Pointer Processor) in the virtual container signal, and much slower in the Administrative Unit (AU) or Tributary Unit (TU) (0 to 1 frame delay per pointer processor). For a certain amount of time the frame start indication, i.e. the pointer at the tandem connection sink node is not aligned with the actual phase of the virtual container. Information will be read from the wrong byte positions during this period of misalignment. This effect increases with the number of pointer processors in the chain.

5 The problem for tandem connection trails is introduced by the fact that there is no separate layer to transport the tandem connection information and that the path (virtual container) layer is used instead. Therefore interruptions on the path (virtual container) layer also influence the tandem connection layer.

10 It is an object of the invention therefore, to reduce the influence of frame offset discontinuities occurring at the beginning of a Tandem Connection Trail in a Synchronous Digital Hierarchy (SDH) or in a Synchronous Optical Network (SONET) System.

15 The invention is defined in independent claims 1 and 15.

20 Based on the invention, frame offset discontinuities are detected and relayed to a network management system where this information is further utilized to initiate predefined process steps.

25 In a preferred embodiment of the invention the signalled information is processed and stored as a kind of transmission quality protocol for a segment of the respective network path provided to a customer. As a consequence thereof, a network provider is enabled to show that the distortion or the fault condition was not caused within the providers network path segment but was received at the entrance or input of the path segment.

30 If the discontinuity condition detected at network element A is transmitted to network element B, which process also is termed throughout the description of the invention as "frame

offset discontinuity inband signalling", then a provider may collect this information for establishing a transmission quality report and filter out faulty or distorted periods of transmission. In addition, storing of the quality data will
5 reveal at any later point of time that, even if certain incoming data were faulty, these data were transmitted essentially without additional distortions along the providers network path segment.

10 In another preferred embodiment, after detection of a discontinuity condition, transmitted pointer values are altered stepwise towards a new valid pointer value (i.e. a valid value after occurrence of the offset discontinuity). Due to the stepwise alteration an uninterrupted or contiguous
15 adaptation from an early undistorted transmission condition to a new undisturbed transmission condition for the TC-relevant data is obtained for the downstream network elements. This adaptation is also named a "smooth" pointer adaptation in the course of the further detailed description.

20 Advantageously, faster smooth adaptation can be obtained if the distance between the last valid pointer value before and the new valid pointer value after the detected discontinuity condition is used to evaluate and select the shortest
25 difference for the stepwise adaptation of the pointer values.

In a further preferred embodiment of the invention the pointer values of a pointer, as received in advance of the discontinuity condition, are transmitted during the time
30 interval used to evaluate the necessary pointer actions (in case of smooth pointer adaptation) or to signal the discontinuity (in case of inband signalling) to avoid transmitting of faulty TC-relevant data during this time

interval.

If after detection and signalling of the discontinuity condition, the tandem connection monitoring (TC) system
5 suspends counting and evaluating of errors and failures for a predefined interval of time and this interval of time is chosen to be sufficient for covering the period of time necessary for compensating the discontinuity condition,
suspending is of no negative influence but beneficial as it
10 is not desired to report any TC failures and errors caused by the ingressing discontinuity.

Moreover, in case that after detection of the discontinuity condition, collection or reporting of errors and failures is
15 interrupted for a predefined interval of time and this interval of time is chosen to be long enough for covering the period of time necessary for compensating the discontinuity condition, it is ascertained that a provider receives only undistorted TC-relevant data. It is assumed that the
20 necessary interval of time during which the data transmission fails is within the allowed range for the relevant network applications.

The invention is described in more detail in connection with
25 the appended drawings and in view of preferred embodiments in which

Fig. 1 shows the functional model for a VC-4 path from
Network Domain I via Network Domain II to
30 Network Domain III with an embedded VC-4 tandem connection trail in Network Domain II between Network Elements (NE) A and B;

Fig. 2 details a High-Level View of the Lucent PHASE

System Architecture;

Fig. 3 shows a block overview of a smooth pointer adaptation at the TCM Source Function Block;

Fig. 4 explains different cases for a pointer distance calculation for the smooth pointer adaptation mode;

Fig. 5 shows a block overview of frame offset discontinuity inband signalling at the TCM Source Function Block;

Fig. 6 shows a block overview of frame offset discontinuity signalling at the TCM Sink and TCM NIM function block;

Fig. 7 shows a freeze process for TCM Sink and TCM NIM Defect Evaluation;

Language, terminology and definitions are used throughout the description and in the claims in accordance to the respective international and national standard notation, i.e. unless other definitions were made in view of specific terms.

Definitions and Glossary

In addition to definitions given in the introductory portion of the description, a synchronous hierarchic system according to the invention is an SDH or SONET system or a system including path sections between network elements NE including the essential features of SDH or SONET systems.

The term "frame offset discontinuity" in connection with the invention is intended to cover an alteration of the

pointer value other than an increment or decrement operation that is introduced by the network system and an ingressing discontinuity is meant to cover a discontinuity received by or entering a network element NE.

5

Even if in the following description of the most preferred embodiments only an SDH application is described, the essential principle is also applicable to SONET systems.

10

Figure 1 shows the functional model for a VC-4 path from Network Domain I via Network Domain II to Network Domain III with an embedded VC-4 tandem connection trail in Network Domain II between Network Elements (NE) A and B. The network elements (NEs) A and B are connected via an optical STM-1 link and both NEs are connected to Network Domain I and III via an optical STM-4 link.

15

20

The standards define that in NE A a pointer interpreter is in the adaptation sink function MS4/S4 and a pointer generator in the adaptation source function MS1/S4 with the Tandem Connection Adaptation Source S4D/S4 function and the TC TT Source S4D function between. For the reverse direction there is a pointer interpreter in the adaptation sink function MS1/S4 and a pointer generator in the adaptation source function MS4/S4 with the TC Adaptation Sink function S4D/S4 and the TC TT Sink function S4D between. In principle the same applies for NE B. The following mechanism is used at the TC Adaptation Source function on the transition into an SSF condition (holdover mode): The adaptation sink function MS4/S4 receives a signal with incorrect pointer values. It will count the number for some frames (3 if AIS in pointer, 8 if invalid pointer). During this period the frame start signal CI FS

25

30

is maintained and the SSF indication signal CI SSF is inactive (=FALSE). On detection of a defect (dAIS or dLOP), CI_FS becomes invalid and CI_SSF becomes active (=TRUE). Furthermore, all-1's is inserted into the VC-4 signal. The TC Adaptation Source function S4D/S4 detecting the change in CI FS and CI SSF, enters „holdover" state in its Frame Start circuit, and continues to generate the frame start signal AI FS at the same position as before. It will also activate the signal fail indication signal AI SF.

The TC Trail Termination Source function S4D will continue to receive a valid AI FS signal at the same position as before. It will also receive an active AI SF signal and will insert the IncAIS Code (N1[1-4]=1110) into the signal. Signalling of IncAIS must not start before the mismatch between B3 and the BIP-8 calculated over the previous frame (caused by the start of the all-ones-insertion) is cleared, i.e. not before a complete frame has been overwritten with all-ones. This is not explicitly described in the standards, but is essential to prevent the detection of TC bit errors at the far end. Therefore this procedure is considered as state of the art and is not further mentioned in the following text. The IncAIS code point in the IEC (=Incoming Error Code) field is interpreted as zero errors at the far end, which is correct for the transmission of VC-AIS. During the defect detection time in the adaptation sink function MS4/S4, mismatches between calculated BIP-8 and B3 will be detected as there is an access to a random B3 byte position. They are correctly encoded into the IEC field. As such, the transition will not result in the detection of any errors in the TC. The adaptation source function MS1/S4 receives a continuous CI FS and will not change its pointer value.

In principle an arbitrary frame start discontinuity can also be detected as a change of the frame start signal CI FS entering the TC Adaptation Source function S4D/S4.

5 However many implementations do not follow the standards with respect to the locations of the pointer interpreter and the pointer generator, but have a combined pointer interpreter/generator in the adaptation sink function MSx/S4 and no further pointer handling in the adaptation source
10 function MSx/S4. Therefore a frame offset discontinuity entering the network element with the TC Adaptation Source function is not always accompanied by a new data flag (NDF) in the pointer. Following this kind of implementation also means that the TC Adaptation Source function S4D/S4 must
15 have the functionality of pointer generation in case of SSF (holdover mode).

Scenarios which cause frame offset discontinuities in the network in front of the TC Adaptation Source are listed
20 below. It is also shown which resulting pointer transitions are input to the NE with the TC Adaptation Source function:

- Recovery from Server Signal Fail (SSF) condition (Loss of Pointer (LOP)/AU/TU-AIS) as a result of the repair of a fault or of a protection switch (initiated by a SSF
25 condition)

In this case, the pointer transitions are:

- SSF -> New Data Flag (NDF) -> Norm
- SSF -> Norm

- Establishment of a different path as a result of a
30 crossconnect change in front of the tandem connection trail.

In this case, the pointer transitions are (this also

includes signal changes where typically an Unequipped Signal is used):

- Norm1 -> NDF -> Norm2
- Norm1 -> Norm2

- 5 • Change of phase alignment of byte-synchronously mapped plesiochronous signals. (An example is described in EN 300 417-4-1, Annex C.).

In this case, the pointer transitions are:

- Norm1 -> NDF -> Norm2

- 10 • Protection switches caused by external commands (manual or forced switch), by revertive operation mode or by condition changes which do not affect the pointer (e.g. Signal Degrade)

In this case, the pointer transitions are:

- 15 - Norm1 -> NDF -> Norm2
- Norm1 -> Norm2

The transition from a valid signal into SSF is also a frame offset discontinuity. As this case is considered already in the standards ("Holdover mode for the TC Adaptation Source function") it is not an issue of the further discussion.

20

1. Inventive Problem Solution

To solve the problem, frame offset discontinuities need to be detected at the TC Adaptation Source function. After

25 detection, either an error free tandem connection signal can be inserted at the TC Trail Termination Source function or the frame offset discontinuity can be communicated to the TC Trail Termination Sink function and TC Non-intrusive Trail Termination Sink function to suspend the performance

30 monitoring and the evaluation of the tandem connection defects there for an appropriate period of time.

2.1_ Frame Offset Discontinuity Detection

An incoming frame offset discontinuity occurs if a pointer value is received different from the previous one with NDF set or if three consecutive new, valid and identical pointer values are received without NDF set. Normal stuffing actions are not frame offset discontinuities.

Therefore the detection of the frame offset discontinuity can be achieved by searching for both

- the New Data Flag enabled in the incoming pointer
- three times detection of a new pointer value without NDF (New Pointer Value (NPV))

The pointer transitions that need to be detected are shown in EN 300 417-1-1, Annex B. Figure B1 in this annex shows the pointer interpretation states. All states marked with "NDF_enable" or "3*new_point" are frame offset discontinuities as described above.

2.2_ Procedures to Compensate the Effects of Ingressing Frame Offset Discontinuities

To improve the behaviour of tandem connection trails with respect to ingressing frame offset discontinuities it is intended according to the invention to

- suppress the propagation of frame offset discontinuities into the tandem connection trail by converting the frame offset discontinuities to series of pointer justifications
- signal the incoming frame offset discontinuity to the TC Trail Termination (TC TT) Sink function and TC Non-

intrusive Trail Termination (TC NIM TT) Sink functions and suspend counting and reporting of errors and defects there for a certain period of time

- signal the detected frame offset discontinuity to the network element management and network management system for further processing. (The reporting is done towards the Equipment Management Function (EMF) and then e.g. via the Q-interface to the network element management system.)

2.2.1 FIRST PREFERRED EMBODIMENT, SMOOTH POINTER ADAPTATION

The frame offset discontinuity within the tandem connection trail can be completely suppressed by changing the pointer generation in the Network Element containing the TC Adaptation Source. The idea is to "smooth" the frame offset discontinuity by converting it to a series of consequent pointer actions (increment or decrement) instead of following the jump immediately.

In a first option the distance of the old and new pointer is not taken into account to choose the shortest way of adaptation, but either a sequence of positive or negative justifications is used to go from the last valid pointer value to the new pointer value.

In a second option in order to keep the recovery time for this method as short as possible, the distance between the last valid pointer value and the new valid value after the frame offset discontinuity shall be evaluated. Depending on the distance, either positive or negative justifications shall be used to go from the old pointer value to the new pointer value. During the distance evaluation the last

valid pointer value shall be inserted (holdover mode).

As a further enhancement (third option) the drift direction of the incoming pointer may be evaluated and used for the decision which stuffing direction should be used. This enhancement can be used if the distance for positive and negative justifications is nearly equal.

After the stuffing direction is decided, the pointer generator at the Tandem Connection Monitoring (TCM) source starts inserting pointer justifications. The justification rate shall be as high as feasible but low enough so that it can be propagated through the tandem connection trail without introducing pointer errors.

As soon as the pointer insertion reaches the same pointer value as the incoming signal, a check of the inserted pointer versus the incoming pointer sequence is necessary. If the inserted pointer value is at least three times identical to the incoming pointer, the insertion can be switched off. This check is necessary to prevent the creation of invalid pointer sequences (only every four frames pointer justifications are allowed).

As an option to reduce induced errors behind the tandem connection trail, Incoming AIS (IncAIS) may be signalled via N1/N2 and VC-AIS may be inserted in the path while the smooth pointer adaptation is active. For example such errors would occur if a desynchroniser process accesses random byte positions to detect stuffing information. This could put it beyond its phase adjustment limits.

According to this method, the frame offset discontinuity must not be propagated into the tandem connection trail during the detection period of the frame offset

discontinuity (i.e. until the smooth pointer adaptation starts).

A major advantage of this method is the fact that it requires only modifications at the TC Adaptation Source. This would allow interworking with all equipment containing a standard-compliant TC TT Sink function or TC NIM TT Sink function.

2.2.2_ SECOND PREFERRED EMBODIMENT, FRAME OFFSET DISCONTINUITY INBAND SIGNALLING

The idea of the method of frame offset discontinuity (FOD) inband signalling is to delay the incoming frame offset discontinuity by introducing a holdover mode by a few virtual container frames so that the appearance of a frame offset discontinuity can be communicated within the tandem connection trail from the TC Adaptation Source function to the TC TT Sink function and intermediate TC NIM TT Sink functions.

After detection of the frame offset discontinuity, the pointer generation of the Network Element containing the tandem connection source function shall continue to transmit the pointer value used before the frame offset discontinuity (holdover mode). This is similar to the method used for the transition into SSF.

During the holdover time, a signalling code is inserted in the Tandem Connection Path Overhead (i.e. N1 for VC-4/3 and contiguous concatenated VC-4-Xc TC, N2 for VC-2/12/11 TC).

This code must be selected such that it is not used during normal tandem connection operation and it should be selected such that the operation of Performance Monitoring and Fault Management is not disturbed. For VC-4/3 and VC-4-

Xc TC, a correction of the B3 byte may be necessary, depending on the inserted signalling code.

To keep the holdover phase as short as possible it is recommended to use N1/N2 bits repeated every VC-frame (i.e. bits within the 76 frames tandem connection multiframe should not be used).

The signalling sequence shall be such that a safe transmission even with up to one bit error in the sequence is possible. After the frame offset discontinuity is signalled, the frame offset discontinuity can be propagated into the tandem connection trail.

An alternative option when doing this is not to immediately switch over to the new pointer value after the end of the signalling sequence, but instead to take care that a correct sequence of pointer values is maintained.

At the TC TT Sink function, the frame offset discontinuity code shall be detected out of the N1/N2 bytes. The detection shall tolerate at least one bit error in the signalling code.

After reception of the frame offset discontinuity code, the signal can be assumed as defective for a fixed period of time. During this period, the TC TT Sink function and TC NIM TT Sink function shall stop the accumulation of errors and suspend the usage of tandem connection defects for fault processing and defect second detection. Furthermore, the TC NIM TT Sink function shall suspend the usage of tandem connection defects for sub network connection protection (SNCP) switching.

For this method, the frame offset discontinuity must not be propagated into the TC trail until it is completely

signalled.

2.2.3_ FRAME OFFSET DISCONTINUITY REPORTING

The reporting of frame offset discontinuities can be done
5 directly at the TC Adaptation Source function or (with FOD
inband signalling as described above) at the TC TT Sink
function or TC NIM TT Sink function.

The reported frame offset discontinuities can be used for
event logging or performance monitoring.

3. Application Example

In the TCM application, the described compensation modes
can be activated and used separately per tandem connection
trail. So by means of the network element or network
15 management system each tandem connection trail can be
adapted to the needs of the planned network application. If
the compensation modes are disabled, the TCM function
behaves as required by the current standards. The third
mechanism, to report the detected incoming frame offset
20 discontinuities, is implemented in parallel.

In the application example the functionality of the TC
Adaptation Source function and of the TC TT Source function
is implemented by the TCM Source function block, that of
25 the TC Adaptation Sink function and of the TC TT Sink
function by the TCM Sink function block and that of the TC
NIM TT Sink function by that of the TC NIM function block.

3.1_ Frame Offset Discontinuity Detection

This part is common for all proposed mechanisms.

Goal of the frame offset discontinuity detection is to detect all incoming frame offset discontinuities. As stated above, the pointer transitions that need to be detected are shown in EN 300 417-1-1, Annex B. Figure B1 in this annex shows the pointer interpretation states. All states marked with "NDF_enable" or "3*new_point" are frame offset discontinuities.

In the Lucent Technologies PHASE System Family a pointer processing unit is located in front of the TCM Source function block. The described application relies on the fact that the frame offset discontinuities are detected in the pointer processor unit so that only valid pointers or AU/TU-AIS conditions arrive at the TCM Source function block. The high level view of the Lucent PHASE system architecture is given by Figure 2 .

The table below shows how incoming frame offset discontinuities are converted by the pointer processor unit in front of the TCM Source function block.

| Input to PP Unit: Transition | Input to PP Unit: Condition | Input to TCM Source function block: Pointer sequence generated at PP Unit |
|---------------------------------|--------------------------------|---|
| INC -> NDF | NDF_enable set | Norm -> NDF_enable -> Norm |
| DEC -> NDF | NDF_enable set | Norm -> NDF_enable -> Norm |
| NDF -> NDF | NDF_enable set | Norm -> NDF_enable -> Norm |
| Norm -> NDF | NDF_enable set | Norm -> NDF_enable -> Norm |
| AIS -> NDF | NDF_enable set | AU/TU-AIS -> NDF_enable -> Norm |
| Norm -> | 3*new_point | Norm -> NDF_enable -> Norm |

| | | |
|----------------|-------------|---------------------------------|
| Norm | | |
| INC -> Norm | 3*new_point | Norm -> NDF_enable -> Norm |
| DEC -> Norm | 3*new_point | Norm -> NDF_enable -> Norm |
| NDF -> Norm | 3*new_point | Norm -> NDF_enable -> Norm |
| LOP -> Norm | 3*new_point | AU/TU-AIS -> NDF_enable -> Norm |
| AIS -> Norm | 3*new_point | AU/TU-AIS -> NDF_enable -> Norm |

Looking at the generated pointer sequences in the table above it can be seen that all incoming frame offset discontinuities arrive at the TCM Source function block as a pointer with the NDF_enable set. However, there may be some older equipment which doesn't generate NDF while going from AU/TU-AIS to Norm.

Therefore the conditions that need to be detected at the TCM Source function block are:

- NDF_enable
- Transition AIS -> Non-AIS

For this detection, it is sufficient to check the H1/V1 byte for the following conditions:

- NDF_enable, i.e. NDF-bits in H1/V1 set to "1001". It is not necessary to check for the other valid NDF_enable values, the ss-bit match and the pointer offset value because the transmission from pointer processor unit to TCM source function is system-internal and can be assumed as error-free.
- Transition from an "all-ones" in H1/V1 to any other value to detect the AU/TU-AIS to Non-AIS transition in

case of missing NDF (interworking with old pointer processor units which might not generate an NDF.

5 The two conditions above are detected by a simple one-time pattern match check of the incoming H1/V1 byte per virtual container at the TCM Source function block. The detected frame offset discontinuities are made available for reporting towards the network element management.

3.2_ Smooth Pointer Adaptation

For the smooth pointer adaptation a pointer interpreter and pointer generator with only limited functionality (regarded to what's required in the standards) is implemented. Figure 3 shows a block diagram of the smooth pointer adaptation mechanism at the TCM Source function block.

The pointer interpreter at the TC Adaptation Source function always stores the last valid pointer value. This can be either the last pointer value before entering SSF (if the TC Trail Adaptation Source goes in holdover mode) or the pointer value contained in the AU/TU frame before the frame offset discontinuity.

25 During the smooth pointer adaptation phase, the stored received pointer value is replaced by the last inserted pointer value.

At the occurrence of a frame offset discontinuity, this pointer value is communicated to the TC Adaptation part of TCM Source function block where it is inserted into the outgoing pointer.

As soon as a new valid pointer is available (i.e. directly

after the frame offset discontinuity), the pointer distance between the new valid pointer and the stored pointer value is measured to decide the stuffing direction for the inserted pointer.

5

Figure 4 shows how the pointer distance is calculated. Four cases need to be considered:

- a. (old value > new value) AND (old value - new value) < max./2 -> use decrement operation
- 10 b. (old value < new value) AND (new value - old value) < max./2 -> use increment operation
- c. (old value > new value) AND (old value - new value) >= max./2 -> use increment operation
- 15 d. (old value < new value) AND (new value - old value) >= max./2 -> use decrement operation

The maximum value (max.) is as follows: 782 for VC-4 / VC-4-Xc, 764 for VC-3, 427 for VC-2, 139 for VC-12 and 103 for VC-11.

20

The pointer generation and insertion in the TC Adaptation part of the TCM Source function block inserts stuffing actions every 8th virtual container frame. Using this stuffing rate (and assuming that the incoming pointer value does not drift), the time to reach the incoming pointer is

25

- 392 milliseconds for VC-4 / VC-4-Xc
- 383 milliseconds for VC-3
- 856 milliseconds for VC-2
- 280 milliseconds for VC-12
- 208 milliseconds for VC-11

30

This time may be lengthened by up to 10% if the incoming pointer value drifts with the maximum offset defined for

SDH signals.

If a further frame offset discontinuity occurs while the TC Adaptation part of the TCM Source function block is in the smooth pointer adaptation mode, the distance calculation is retriggered. In this case, the distance between the currently inserted pointer and the new pointer, after the frame offset discontinuity, is calculated and the adaptation is restarted.

During the smooth pointer adaptation period the virtual container is overwritten by an all-ones signal (VC-AIS) in the Adaptation part of the TCM Source function block and Incoming AIS is signalled via N1/N2.

If a SSF condition occurs while the smooth pointer adaptation mode is active, the holdover mode is entered using the previously inserted pointer value.

As soon as the inserted pointer value is equal to the incoming one, a pointer check mode is entered.

- If the inserted pointer is the same as the incoming one for three consecutive times, the insertion is switched off and the incoming pointer is directly passed to the output.
- If a new pointer value is detected at the input (most likely an increment / decrement operation), the smooth pointer adaptation mode is entered again to follow the change of the pointer value.

With the end of the smooth pointer adaptation the all-ones insertion for the virtual container and the signalling of Incoming AIS via N1/N2 is stopped.

3.3_ Frame Offset Discontinuity Inband Signalling

3.3.1_ SIGNALLING MECHANISM

Block diagrams for the FOD inband signalling mechanism are given for the TCM Source function block in Figure 5 and for the TCM Sink and TCM NIM function block in Figure 6.

3.3.1.1_ Operation of the TCM Source Function Block for VC-4, VC-4-Xc and VC-3 TC Trails

After the detection of the frame offset discontinuity, the frame offset discontinuity is signalled into the TC trail by setting bits b1..b4 of byte N1 (IEC = Incoming Error Count) to 1101 for 6 consecutive virtual container frames. This value is normally not used and according to the standard (EN 300 417-4-1) it is interpreted in the TC NIM TT Sink function and in the TC TT Sink function as 0 BIP violations. During the signalling period, the last valid received pointer is inserted (holdover mode). The period of signalling lasts $6 * 125$ us. In order not to misinterpret the incoming BIP-8 violations of the path segment in front of the TC trail as bit errors of the tandem connection trail itself, the BIP-8 value calculated over the previous ingressing frame is inserted at the position of the incoming B3 byte. After this correction the normal processing of the TC TT Source function (i.e. N1 modification and B3 compensation, see EN 300 417-4-1) is carried out. To replace the incoming B3 byte by the BIP-8 value calculated by the TC TT Source part of the TCM Source function block is not a problem as due to the frame offset discontinuity the byte accessed as "B3" is more than likely not the BIP-8 value originally inserted at the begin of the path.

After the end of the signalling phase the holdover mode for the pointer is left and the ingressing pointer is passed through transparently.

3.3.1.2_ Operation of the TCM Sink and TCM NIM Function Block for VC-4, VC-4-Xc, and VC-3 TC Trails

The frame offset discontinuity detection process at the sink function monitors bits b1..b4 of byte N1. If the reserved value 1101 is received in 3 consecutive virtual container frames the TCM Sink and TCM NIM function blocks will enter the "frame offset discontinuity suspension state". If there is no retriggering the suspension state will be left with the next but one 1-second tick. So the duration of the suspension state is at least one second. (A central one second tick is available in the system which e.g. is also used for performance monitoring purpose). However, if a SSF condition is detected during the FOD suspension state, the FOD suspension state will immediately be left and normal operation will be re-established. The transition into the FOD suspension state is reported towards the network element management system.

3.3.1.3_ Operation of the TCM Source Function Block for VC-2, VC-12, VC-11 TC Trails

After the detection of the frame offset discontinuity, the frame offset discontinuity is signalled into the tandem connection trail by inserting the alternating pattern 01, 10 into bits b3, b4 of byte N2 for 7 consecutive VC-2 / VC-12 / VC-11 frames. Bit b3 is normally fixed to 1, and b4 indicates Incoming AIS. During the signalling period, the last valid received pointer is inserted (holdover mode). The period of signalling lasts $7 * 500$ us. After the end of the signalling phase the holdover mode for the pointer is

left and the ingressing pointer is passed through transparently.

5 **3.3.1.4_ Operation of the TCM Sink and TCM NIM Function Block for VC-2, VC-12, VC-11 TC Trails**

10 The frame offset discontinuity detection process at the sink function monitors bits b3, b4 of byte N2. If the reserved pattern sequence 01, 10, 01 is received (this will take 3 VC frames) the TCM Sink and TCM NIM function block will enter the "frame offset discontinuity suspension state". If there is no retriggering the suspension state will be left with the next but one 1-second tick. So the duration of the suspension state is at least one second. (A
15 central one second tick is available in the system which e.g. is also used for performance monitoring purpose). However, if an SSF is detected during the FOD suspension state, the FOD suspension state will immediately be left and normal operation will be re-established.

20 The transition into the FOD suspension state is reported towards the network element management system.

3.3.2_ OPERATION DURING THE FRAME OFFSET DISCONTINUITY SUSPENSION STATE

25 In principle three requirements have to be fulfilled by the TCM Sink function block and the TCM NIM function block:

- Do not extend the interruption of the signal
- Suppress all effects of the frame offset discontinuity for the fault management and performance monitoring
- 30 • Do not use tandem connection defect condition changes for SNCP switching

3.3.2.1 Handling of Defects

In order to minimize the signal interruption the defect detection processes are not affected by the frame offset discontinuity suspension state, i.e. it cannot be ruled out that defects are detected during the phase of misalignment between pointer and transported signal. However there is a modified processing of the defects and performance monitoring primitives during the frame offset discontinuity suspension state. For this purpose the state of the tandem connection defects dUNEQ, dLTC, dTIM, dDEG, dRDI, dODI, dIncAIS is frozen with the transition into the frame offset discontinuity suspension state. The frozen versions of these tandem connection defects are called dUNEQ', dLTC', dTIM', dDEG', dRDI', dODI', dIncAIS' and are made available as latched copies for further processing (consequent action handling, defect correlation, performance monitoring). However this additional latching of the tandem connection defects does not suspend the tandem connection defect detection processes. The freeze of the defects is shown for example by the block diagram of Figure 7. The defect storage becomes transparent when the FOD suspension state is inactive.

The relations below are valid in case that CI_SSF is inactive, otherwise the FOD suspension state is left. The relations are quite similar to those used in the normal operation state, however partially the frozen versions of the tandem connection defects are used in the FOD suspension state.

3.3.2.2 Detection of Bit Errors

The detection of nN_B, nON_B, nF_B, nOF_B is stopped during the frame offset discontinuity suspension phase.

3.3.2.3 Consequent Actions:

The following modified consequent action handling is used during the frame offset discontinuity suspension state:

```

aAIS    <- dUNEQ or dTIM or dLTC
aTSF    <- CI_SSF or dUNEQ' or dTIM' or dLTC'
aTSD    <- dDEG'
aARDI   <- CI_SSF or dUNEQ' or dTIM' or dLTC'
aREI    <- nN_B
aODI    <- CI_SSF or dUNEQ' or dTIM' or dLTC' or
dIncAIS'
aOEI    <- nON_B
aOSF    <- CI_SSF or dUNEQ or dTIM or dLTC or dIncAIS

```

Rationals:

- aAIS and aOSF are used for insertion of AIS in the TC TT Sink and TC Adaptation Sink function. As the egressing signal shall not be interrupted for a fixed time but shall recover as soon as possible, the actually detected defects are used here.
- aTSF and aTSD are used as switching criteria for TC NIM TT based SNCP. As there shall be no protection switches caused by incorrectly detected tandem connection defects during the frame offset discontinuity suspension state, the frozen tandem connection defects are used here.
- aTSF is also used for detection of defect seconds pN_DS. Also here the frozen states of the tandem connection defects shall be used.
- aARDI is used for insertion of the corresponding remote information into the reverse direction. To get a consistent view to the performance monitoring it should

be identical with aTSF which is used for pN_DS,
therefore also here the frozen states of the tandem
connection defects are used.

- aODI is used for insertion of the corresponding remote
information into the reverse direction and for detection
of defect seconds pON_DS. Also here the frozen states of
the tandem connection defects are used.
- aREI and aOEI will not indicate errors towards the
remote end as the detection of bit errors is stopped
during the frame offset discontinuity suspension state.

3.3.2.4_ Defect Correlations

The following modified defect correlations are used during
the frame offset discontinuity suspension state:

```

cUNEQ    <- MON and dUNEQ'
cLTC     <- MON and (not CI_SSF) and (not dUNEQ') and
dLTC'
cTIM     <- MON and (not dUNEQ') and (not dLTC') and
dTIM'
cDEG     <- MON and (not dTIM') and (not dLTC') and
dDEG'
cSSF     <- MON and CI_SSF and SSF_reported
cRDI     <- MON and (not dUNEQ') and (not dTIM') and
(not dLTC') and dRDI' and RDI_Reported
cODI     <- MON and (not dUNEQ') and (not dTIM') and
(not dLTC') and dODI' and ODI_Reported
cIncAIS  <- MON and (not CI_SSF) and (not dTIM') and
(not dLTC') and dIncAIS' and
IncAIS_Reported

```

Rationals:

- The frozen states of the tandem connection defects are used for the defect correlation. So also the reporting of the faults will be frozen during the frame offset discontinuity suspension state.

5

3.3.2.5 Performance Monitoring

The following modified determination of the performance monitoring primitives is used during the frame offset discontinuity suspension state.

10

```
pN_DS      <- aTSF or dEQ
pF_DS      <- dRDI'
pN_EBC     <-  $\sum nN\_B$ 
pF_EBC     <-  $\sum nF\_B$ 
pON_DS     <- aODI or dEQ
pOF_DS     <- dODI'
pON_EBC    <-  $\sum nON\_B$ 
pOF_EBC    <-  $\sum nOF\_B$ 
```

15

20

Rationals:

- The accumulation of bit errors during the frame offset discontinuity suspension state is suspended as the detection of bit errors is stopped in this state.
- For the detection of defect seconds the frozen states of the tandem connection defects are used, therefore also the defect second detection is frozen during this period.

25

Claims

1. A method of transmitting data in a synchronous
hierarchical network system comprising at least a path
segment between a first network element (A) and at least
a second network element (B) on which tandem connection
monitoring (TC) method is established for monitoring
transmission of information over said path segment,
characterised by

detection of frame offset discontinuities at said
first network element (A) on the basis of the detection
of an alteration of the pointer value.

2. The method of transmitting data according to claim
1, wherein the discontinuity condition is signalled to
an equipment management system.

3. The method of transmitting data according to claim
2, wherein the signalled discontinuity condition
information is stored in a transmission quality report.

4. The method of transmitting data according to claim
1, wherein the discontinuity condition detected at the
first network element (A) is transmitted to the second
network element (B).

5. The method of transmitting data according to claim
4, wherein the discontinuity condition detected at the
first network element (A) is transmitted within a
defined data element of a virtual container transmitted
to the second network element (B).

6. The method of transmitting data according to claim 4 or 5, wherein after detection and signalling of the discontinuity condition the second network element (B) suspends counting and evaluation of certain TC errors and defect information for a predefined interval of time.

7. The method of transmitting data according to one of the claims 4 to 6, wherein the discontinuity condition is signalled from a second network element (B) to an equipment management system.

8. The method of transmitting data according to claim 7, wherein the signalled discontinuity condition information is stored in a transmission quality report.

9. The method of transmitting data according to claim 1, wherein after detection of a discontinuity condition transmitted pointer values are altered stepwise at the first network element (A).

10. The method of transmitting data according to claim 9, wherein the stepwise alteration is comprising a pointer value adjustment towards a new valid pointer value and

at each step introduction of a pointer value difference which is within the standardised range of pointer increment or decrement operations.

11. The method of transmitting data according to claim 9 or 10, wherein the distance between the last valid pointer value before and new valid pointer value after the detected discontinuity condition is used to evaluate

and select the shortest difference for the stepwise adaptation of the pointer values.

12. The method of transmitting data according to one of claims 9 to 11, wherein in case of similar differences for increasing or decreasing of the pointer value evaluated at the evaluation step, the direction of the pointer drift before the discontinuity condition occurred is used to determine the direction for the stepwise pointer adaptation.

13. The method of transmitting data according to claim 4 or 9, wherein during the time interval necessary for the detection and transmission of the frame offset discontinuity the last valid pointer received in advance of the discontinuity condition, is transmitted.

14. The method of transmitting data according to anyone of claims 1 to 13, wherein the first network element (A) operates as a source network element and the second network element (B) operates as a sink network element.

15. A synchronous hierarchic network system, especially adapted to a data transmission method according to one of claims 1 to 14, comprising

at least a path segment between a first network element (A) and at least a second network element (B) on which a tandem connection monitoring (TC) method is established for monitoring information over said path segment,

characterised by

means for detection of frame offset discontinuities on the basis of the detection of an alteration of the

pointer value.

16. The synchronous hierarchic network system according to claim 15 comprising means for signalling the frame offset discontinuity condition to an equipment management system.

17. The synchronous hierarchic network system according to claim 15 or 16, further comprising means for receiving and storing of discontinuity condition information received from the detection means.

18. The synchronous hierarchic network system according to claim 15, further comprising means for evaluating and altering of pointer values.

19. The synchronous hierarchic network system according to claim 15, comprising means for transmitting the discontinuity condition detected at the first network element (A) to the second network element (B).

20. The synchronous hierarchic network system according to claim 9, comprising

means for suspending the counting and evaluation of certain TC errors and defect information for a predefined interval of time.

21. The synchronus hierarchic network system according to anyone of claims 15 to 20, wherein the first network element (A) operates as a source network element and the second network element (B) operates as a sink network element.

FIG. 1

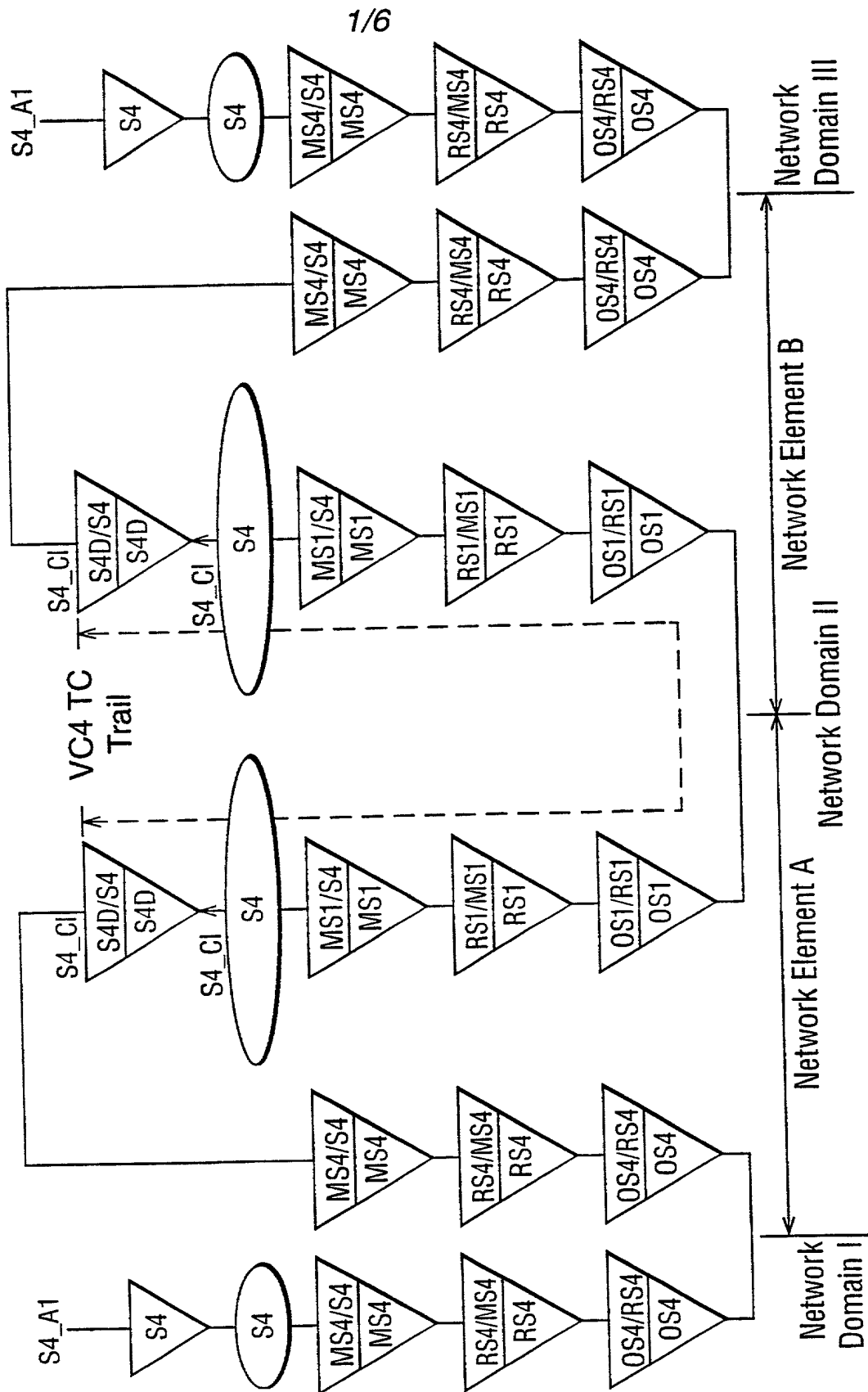


FIG. 2

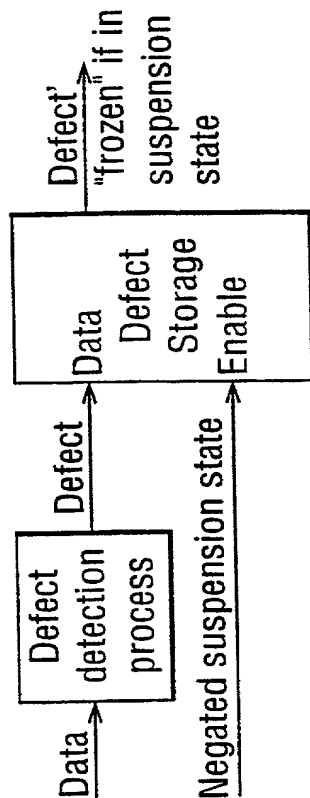
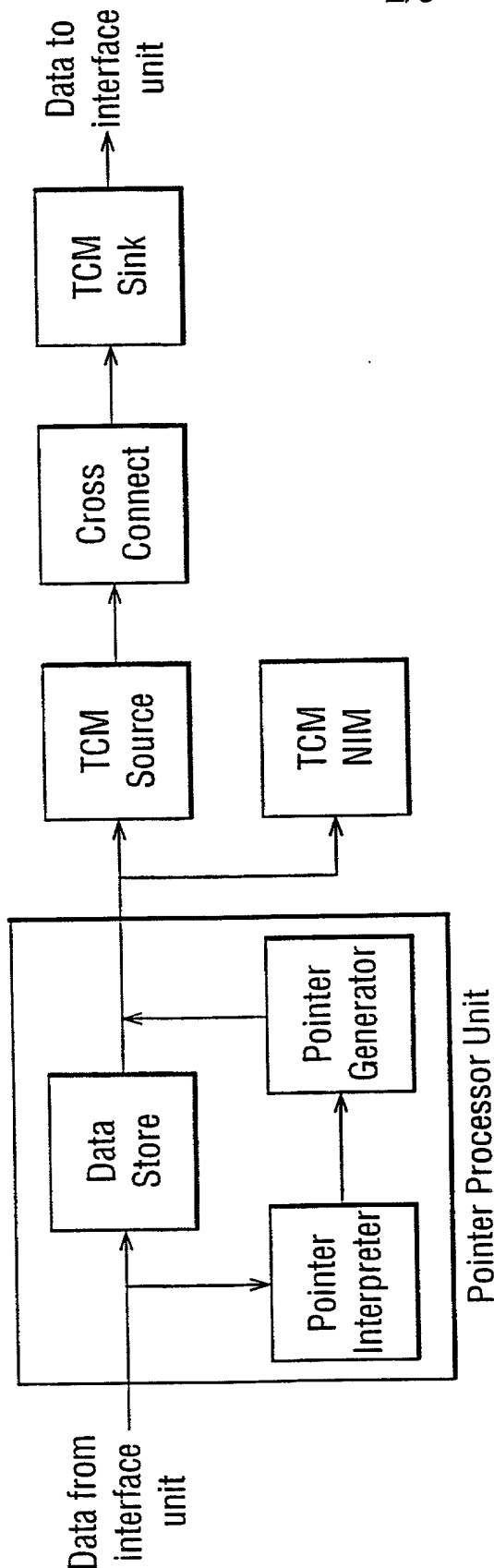
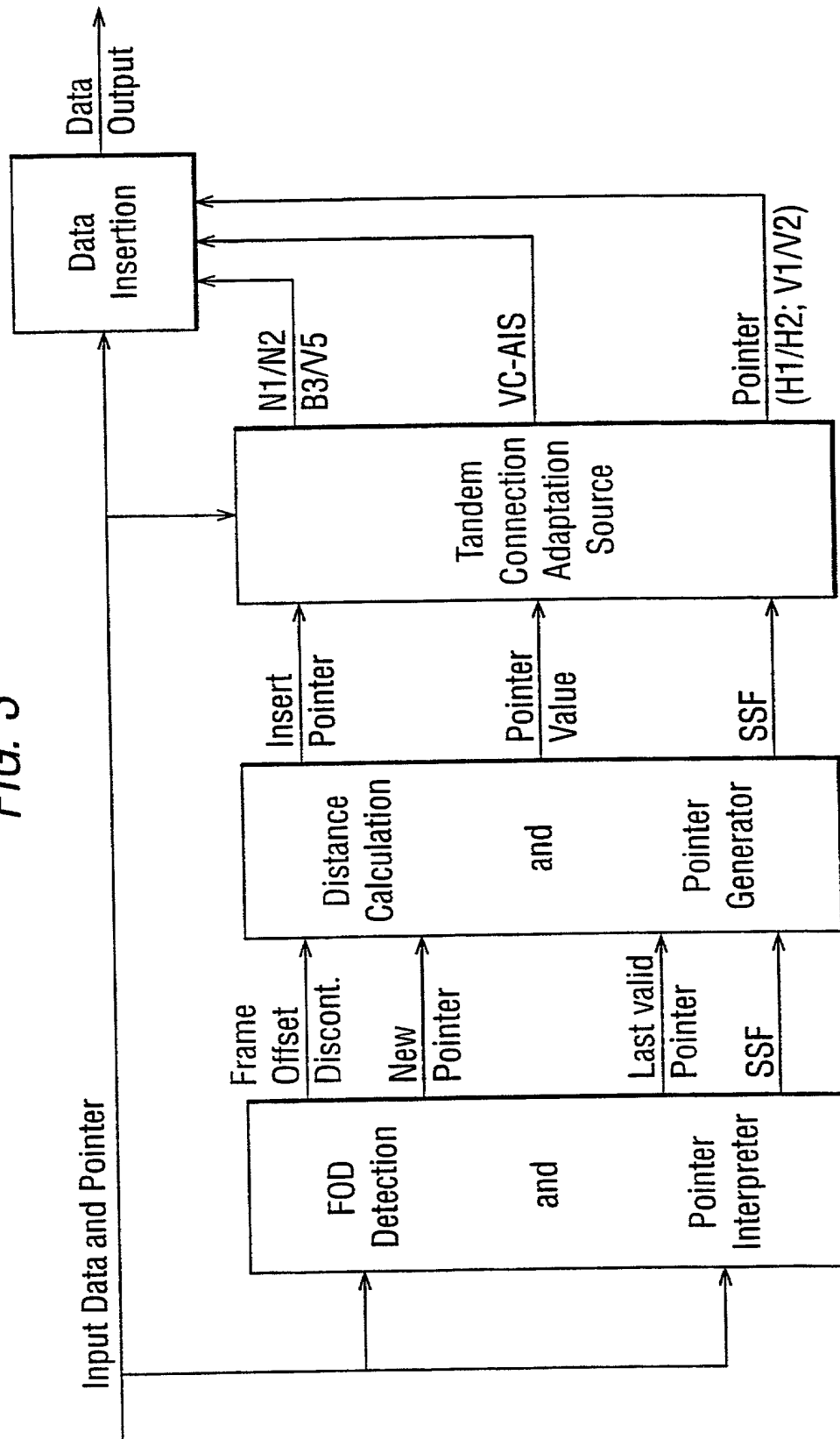


FIG. 7

The defect storage is transparent if the freeze process is not in the suspension state.

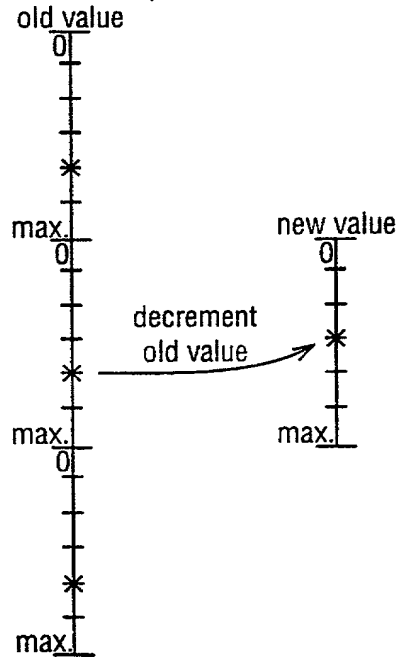
FIG. 3



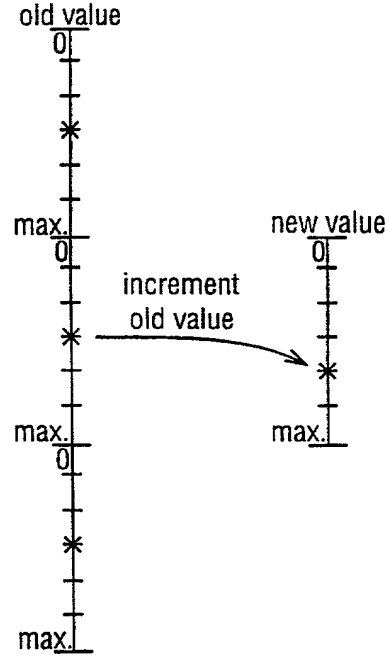
4/6

FIG. 4(a)

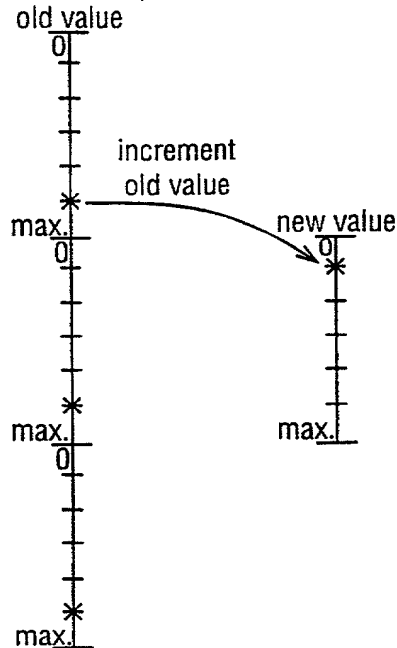
(old value > new value) AND
 (old value - new value) < max./2

**FIG. 4(b)**

(old value < new value) AND
 (new value - old value) < max./2

**FIG. 4(c)**

(old value > new value) AND
 (old value - new value) >= max./2

**FIG. 4(d)**

(old value < new value) AND
 (new value - old value) >= max./2

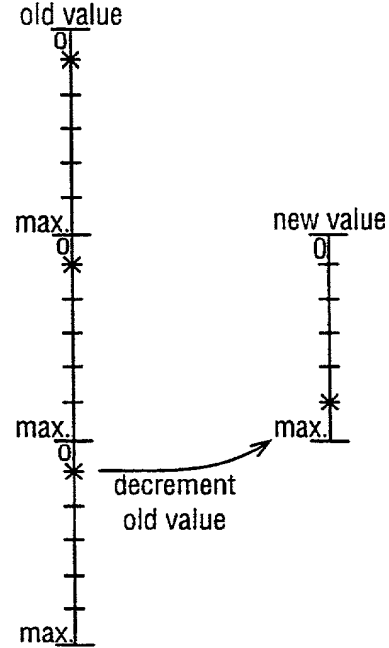


FIG. 5

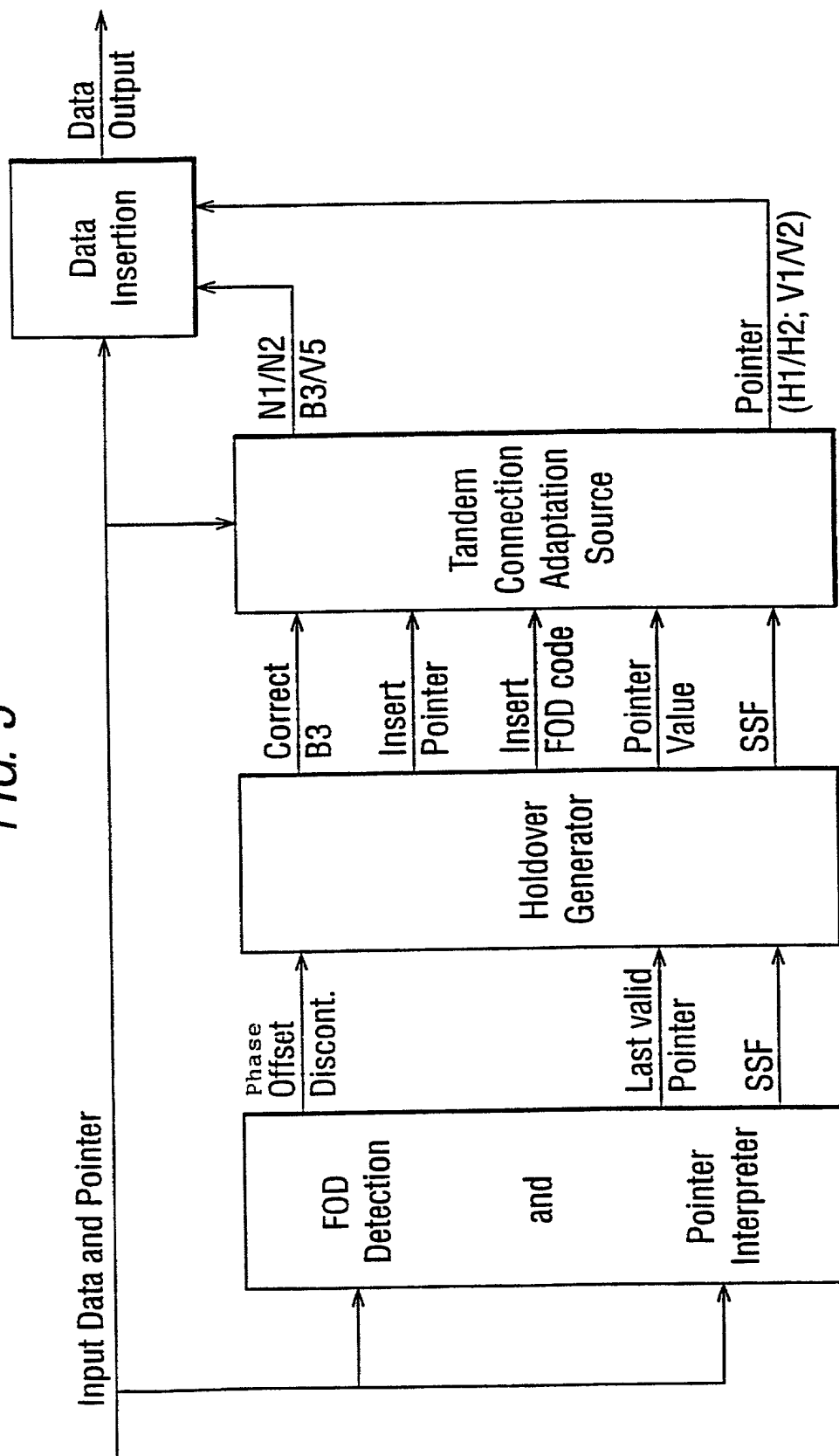
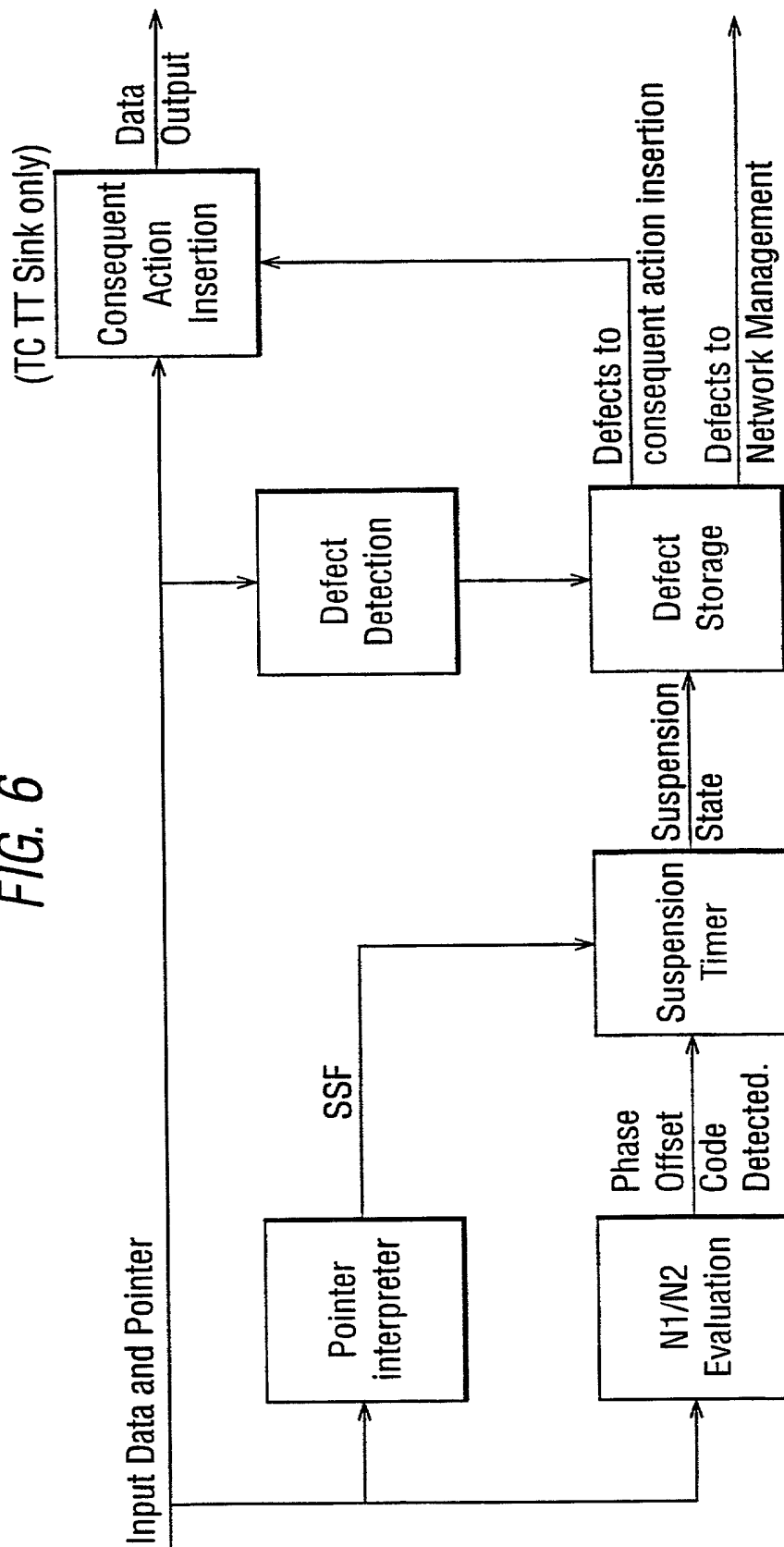


FIG. 6



IN THE UNITED STATES
PATENT AND TRADEMARK OFFICE

Declaration and Power of Attorney

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name.

I believe I am an original, first and joint inventor of the subject matter which is claimed and for which a patent is sought on the invention entitled **Detection And Compensation Of Ingressing Frame Offset discontinuities For Tandem Connection Trials** the specification of which

☒ is attached hereto

OR

☐ was filed on _____ and granted Application Serial Number _____.

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by an amendment, if any, specifically referred to in this oath or declaration.

I acknowledge the duty to disclose all information known to me which is material to patentability as defined in Title 37, Code of Federal Regulations, 1.56.

I hereby claim foreign priority benefits under Title 35, United States Code, 119 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

99106363.7 March 29, 1999

I hereby claim the benefit under Title 35, United States Code, 120 of any foreign application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, 112, I acknowledge the duty to disclose all information known to me to be material to patentability as defined in Title 37, Code of Federal Regulations, 1.56 which became available between the filing date of the prior application and the national or PCT international filing date of this application:

None

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

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FOI260 4982660

I hereby appoint the following attorney(s) with full power of substitution and revocation, to prosecute said application, to make alterations and amendments therein, to receive the patent, and to transact all business in the Patent and Trademark Office connected therewith:

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